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Control of the Meadow Spittlebug on Forage Crops

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Preliminary investigations of the control of the meadow spittlebug, *Philaenus leucophthalmus* L., and its variations in forage crops were begun in 1948. At that time, the tests were conducted with a view toward finding an insecticide which would kill the insect rather than develop a practical control program. Since the meadow spittlebug spends a portion of its life cycle in an inactive stage enveloped in froth while attached to the stem of a plant and a portion of its life cycle moving freely about as an adult, various methods of control were investigated during the two stages of its life history.

In 1949 dust treatments were emphasized using the most effective materials found to control the nymph of the meadow spittlebug in 1948, while the 1950 experiments were designed to find the minimum effective concentrations of several insecticides as sprays and dusts to control the nymph of the meadow spittlebug.

METHODS AND MATERIALS.—Sprays, dusts and thermal aerosols were applied in many tests conducted over the three year period, but only a few will be described in this paper. The dust treatments were applied by a rotary hand duster, a hand fertilizer distributor and an alfalfa even-feed power duster.[2]

The sprays were applied by a knapsack sprayer, a trailer-type weed sprayer and a power take-off low pressure weed killer type spray rig mounted on a tractor. The boom on the trailer-type weed sprayer was 20 feet in length and was equipped with 15 fan type nozzles[3] while the tractor mounted sprayer had a boom which was eighteen feet in length equipped with thirteen fan type nozzles.[3] Forty pounds pressure was maintained with the trailer-type weed sprayer while 30 pounds pressure was used with the tractor mounted sprayer in all experiments.

Aerosols were applied by means of a standard manufactured thermal aerosol applicator. The machine settings during the operation remained fixed at an air pressure of 3.25 pounds, a gasoline pressure of 40 pounds per square inch, and an air temperature before the nozzle outlet of 1000° F.

All the test plots were randomized and replicated three times in each experiment. The size of the plots, however, varied with the type of applicator used. The even-feed power duster plots were 20 by 200 feet in size whereas the rotary hand duster plots and fertilizer distributor plots were 10 by 20 feet. Spray applications with the low pressure equipment were made to plots 20 by 80 feet in size while the knapsack sprayer plots were 10 by 20 feet. Aerosol applications were made to plots approximately 1 acre in size.

Adult spittlebug counts were made in random areas by taking 25 full arm single sweeps with a short handled (20 inch) 15 inch net in each plot at the various times designated in the tables. Nymphal counts were taken by examining three 1 square yard areas chosen at random in every plot and recording the number of spittle masses found.

In 1948, six tests were conducted for the control of the meadow spittlebug, three of which were concerned with the adult insect and three with the nymph. Benzene hexachloride, which was applied as a spray by knapsack sprayer at the rate of 2 pounds of actual gamma isomer per acre, gave 100 per cent control of the nymphs 3 weeks after application whereas chlordane and DDT applied at the same time at similar concentrations did not give satisfactory results. (Table 1). Thermal aerosols at machine settings of 10,

[1] The authors wish to express gratitude to the following men who assisted in the work reported in this paper: Arthur Muka, Lemac Hopkins and Robert Burrage.

[2] Niagara Spray and Chemical Model AA even-feed duster powered with a Briggs and Stratton Model ZZ engine.

[3] Teejet No. 650067.

20, 40 and 60 microns were tested for the reduction of the nymph of the spittlebug and poor results were obtained at all except the highest setting. In the largest thermal aerosol particle size experiment, benzene hexachloride was probably more effective not only because of its specificity for spittlebug control but also because the alfalfa was sparse and better penetration coverage was obtained. In another sector of the alfalfa field where the growth was heavy, much less satisfactory penetration, coverage and control was obtained with the other materials. These results may be seen in table 2. Although ideal atmospheric conditions prevailed when the field described above was treated, thermal air currents and strong winds greatly limit the use and effectiveness of thermal aerosols during most days throughout the summer in northern New York.

In Experiment 3 (Table 3) dust applications were made with a power duster for the control of the adult spittlebug in a first crop year red clover field. Net sweeps taken 48 hours after application revealed immediate effective control with benzene hexachloride, chlordane and TDE. However, counts made 3 weeks after treatment showed little to no control as the populations quickly built up again in the treated plots. Similarly, in other tests for the control of the adults of the meadow spittlebug, immediate good kills were obtained with several insecticides but in a short time the populations of the treated plots equalled or exceeded those of the untreated plots.

Since the injury caused by the feeding of the adult meadow spittlebug is not as great as that caused by the nymphs, the 1949 experiments emphasized control of the nymphal stage.

Table 1.—A comparison of three chlorinated hydrocarbon insecticides when applied as sprays by a knapsack sprayer for the control of the nymph of the meadow spittlebug. Fulton, N. Y., June 1, 1948.

Material	Actual Toxicant in Lbs./Acre	Avg. No. Masses per Sq. Yd.	Per Cent Reduction
		3 week count	
BHC	2.0	0	100.0
Chlordane	2.0	8	46.6
DDT	2.0	8	46.6
Check	—	15	—

Table 2.—Summary of the control data for the nymph of the meadow spittlebug with four chlorinated hydrocarbon insecticides applied as thermal aerosols[1] on June 20, 1948. Minetto, N. Y.

Material	Per Cent Solutions	48 Hour Count: Feet from Nozzle	48 Hour Count: Masses Examined	Per Cent Nymphs Dead
BHC	1.0	10	25	100.0
		20	25	90.0
		30	25	60.0
Dieldrin	1.0	10	25	100.0
		20	25	50.0
		30	25	0.0
Toxaphene	1.0	10	25	60.0
		20	25	30.0
		30	25	0.0
Aldrin	1.0	10	25	10.0
		20	25	0.0
		30	25	0.0

[1] Micron setting: 60.
Air pressure: 3.25 pounds.
Air temperature: 1000° F.
Fuel pressure: 45 pounds.

In 1949, three series of experiments (Table 4) were conducted with the dual purpose of determining if a single insecticide application, applied at the time the clover root borer was in flight, would control both the borer and the meadow spittlebug. These tests were applied by a fertilizer distributor to a first crop year medium red clover field which was approximately 6 to 8 inches high at the time of application. Benzene hexachloride at concentrations as low as 0.50 pound of actual gamma isomer per acre gave

Table 3.—Results from 1948 field tests comparing the effectiveness of BHC, chlordane, TDE and DDT dusts applied by the power duster for the control of the adult meadow spittlebug. Fulton, N. Y., July 21, 1950.

Material	Toxicant in Lbs./Acre	Adults per 20 Sweeps	Per Cent Reduction
		48 Hour Count	
BHC	1.00	0	100.0
Chlordane	2.25	0	100.0
TDE	2.25	0	100.0
DDT	2.25	3	78.6
Check	—	14	—
		3 Week Count	
BHC	1.00	5	28.6
DDT	2.25	6	14.3
Chlordane	2.25	10	—
TDE	2.25	13	—
Check	—	7	—

Table 4.—Effect of treatment with BHC, parathion, methoxychlor, dieldrin, aldrin, toxaphene and chlordane as dusts applied by a fertilizer distributor to control the nymph of the meadow spittlebug. Fulton, N. Y. May 12, 1949.

Material	3 Week Count: Toxicant in Lbs./Acre	3 Week Count: Nymphs per Sq. Yd.
BHC	0.50	0.0
BHC	0.75	0.0
BHC	1.00	0.0
BHC	1.25	0.0
Parathion	0.50	2.6
Parathion	0.75	4.3
Parathion	1.00	3.6
Parathion	1.25	4.3
Check	—	10.3
L.S.D. at the 5% level		9.1
Experiment 2		
BHC	1.00	0.0
Dieldrin	2.00	0.0
Aldrin	2.00	0.0
Toxaphene	4.00	0.0
Methoxylchlor	4.00	0.0
Chlordane	2.00	0.0
Chlordane	1.50	0.6
Parathion	1.00	3.6
Check	—	9.6
L.S.D. at the 5% level		3.2
L.S.D. at the 1% level		4.6

excellent control of the nymph of the spittlebug while concentrations as high as 1.25 pounds of parathion per acre did not give satisfactory results. In the final test of the series, benzene hexachloride, dieldrin, chlordane, aldrin, toxaphene and methoxychlor were applied and all materials gave excellent control. In Experiment 5 (Table 5), using impregnated dusts at the rate of one pound of actual toxicant

Table 5.—A comparison of four synthetic organic insecticides applied as impregnated dusts by a fertilizer distributor for the control of the meadow spittlebug nymph. May 26, 1949.

Material	2 Week Count: Toxicant in Lbs./Acre	2 Week Count: Masses per Sq. Yd.	Per Cent Reduction
BHC	1.00	0	100.0
Chlordane	1.00	2	86.7
DDT	1.00	5	66.7
Parathion	1.00	11	26.7
Check	—	15	—
L.S.D. at the 5% level			52.7%
L.S.D. at the 1% level			87.5%

Table 6.—Effect of treatment using benzine hexachloride, methoxychlor, dieldrin, toxaphene, chlordane, parathion and aldrin as dusts applied by a rotary hand duster on the nymph of the meadow spittlebug. Fulton, N. Y. May 24, 1949

Material	Toxicant in Lbs./Acre	Living Nymphs in 30 Masses	Per Cent Reduction
BHC	1.00	0	100.0
Methoxychlor	10.0	1	98.8
Dieldrin	2.5	3	96.4
Toxaphene	10.0	9	89.2
Chlordane	5.0	10	88.0
Parathion	2.0	22	73.5
Aldrin	2.5	32	61.5
Check	—	83	—
L.S.D. (19:1)			84.7%
L.S.D. (99:1)			93.9%

per acre, benzene hexachloride was again the only material found to be effective. The final test for the year 1949 (Table 6) was a rotary hand dust application experiment using proprietary materials at the rate of 150 pounds of dust to the acre. Benzene hexachloride, dieldrin and methoxychlor all gave excellent control at the concentrations at which they were used, but benzene hexachloride was much superior to the other two materials tested since it was used at a much lower dosage. Toxaphene, chlordane, parathion, and aldrin, in that order, gave good results but were inferior to the other toxicants tested.

The results obtained in 1949 showed that the most effective control of the meadow spittlebug was obtained through the suppression of the nymphal stage and that benzene hexachloride and dieldrin were apparently the most effective toxicants. The aim of the 1950 program therefore was to find the minimum concentration of these materials needed to control the nymph of the spittlebug and to explore further some of the more recently discovered insecticides. The availability of low pressure spray equipment also enabled a comparison to be made between spray and dust applications on a large commercial scale.

In Experiment 7 table 7, a test designed as a latin square was laid out to determine the earliest pre-emergence dusting date for effective control of the meadow spittlebug. The field chosen for the experiment was a first crop year red clover field. At weekly intervals commencing April 18, one series of seven plots each received one

Table 7.—A summary of the control data using lindane to determine the earliest pre-emergence dusting date for the control of the meadow spittlebug. Fulton, N. Y. 1950.

Date Applied	Replications: Spittle Masses per Sq. Yd. per Plot							Masses per Sq. Yd./ Treat.
	1	2	3	4	5	6	7	
April 18	22	32	39	28	32	30	39	31.7
April 25	23	33	22	25	23	17	22	23.5
May 2	10	14	9	15	16	20	20	14.9
May 9	2	3	2	3	6	1	4	3.0
May 16	3	2	3	3	3	3	3	2.9
May 23	2	2	1	5	6	5	3	3.4
Check	24	39	44	57	57	39	51	44.4
Least significant difference at the 5% level								14.1
Least significant difference at the 1% level								21.4

pound of lindane per acre. At the end of the sixth week, forty-two plots had received one application of lindane and seven plots were left untreated. The first spittle mass was observed in the field on May 9, the fourth week after the weekly dusting had begun. Counts made 2 weeks after the last series of dusts were applied revealed that the earliest effective pre-emergence dusting date was no sooner than one week before egg hatching. Dusts applied four and three weeks previous to the emergence of the nymph gave only small reductions of 28 and 47 per cent, respectively, over the check. Insecticide applications made for at least 2 weeks after egg hatching gave excellent control of between 93 and 95 per cent. It should be remembered however that the later the dusts are applied, the more risk is involved in the residue appearing on the hay at harvest time. Furthermore, the nymphs are easiest to kill with a smaller amount of toxicant near hatching time. Therefore insecticides should be applied as close to the earliest appearance of the nymphs as possible.

Spray applications were made also at weekly intervals throughout the nymphal cycle of the spittlebug in 1950. Eight different insecticides were applied at various concentrations with both the trailer-type weed sprayer and the tractor power type weed sprayer. To elaborate on only one of these tests here, it may be seen in Experiment 8 table 8, that in a comparison of seven of the eight materials tested, benzene hexachloride was best although at the higher concentrations, there were no significant differences in the controls from the use of benzene hexachloride or dieldrin. Toxaphene, purified DDT and heptachlor were slightly less effective than the two previously mentioned materials

Table 8.—Effect of treatment with benzene hexachloride, dieldrin, toxaphene, DDT[2], P-DDT[1], Heptachlor and TM-3[3] as sprays at various concentrations against the nymph of the meadow spittlebug. June 7, 1950.

Material	Act. Tox. Lbs./per Acre	3 Week Count: Splittle Masses per Sq. Yd.	Per Cent Reduction
BHC	0.10	11.6	70.4
	0.20	1.0	97.5
	0.30	0.0	100.0
Dieldrin	0.10	17.0	56.7
	0.20	4.0	89.8
	0.30	0.3	99.2
Toxaphene	0.10	25.0	36.3
	0.20	11.0	72.0
	0.30	5.6	85.7
P-DDT[1]	0.10	34.0	13.4
	0.20	10.0	74.5
	0.30	4.3	89.0
Heptachlor	0.10	32.3	17.8
	0.20	11.6	70.4
	0.30	3.6	90.8
DDT[2]	0.10	41.3	—
	0.20	12.6	67.9
	0.30	8.3	78.8
TM-1[3]	0.10	36.0	8.3
	0.20	21.3	45.8
	0.30	12.0	69.4
Check	—	39.3	—

[1] P-DDT: (Geigy) 20% para-para DDT (purified), 5% aromatic petroleum derivatives.
[2] 25% Technical DDT emulsifiable concentrate.
[3] 1 part,2-nitro-1,1 bis(p-chlorophenyl) propane and 2 parts; 2 nitro-1,1bis(p-chlorophenyl)butane—(*Dilan*).

while DDT and TM-1 although offering fair control at the higher concentrations were the least satisfactory in this experiment.

Since benzene hexachloride and lindane were the most effective insecticides tested during 1950 for the control of the meadow spittlebug, a summary of all the 1950 benzene hexachloride spray and lindane dust application experiments are presented in table 9. As the age of the nymph increased over a 2-week period, the effectiveness of single benzene hexachloride spray applications at the rate of 0.05 pound dropped from 98 to 80 per cent. Similarly, using benzene hexachloride at a concentration of 0.10 pound over a month's series of tests, the effectiveness of the application dropped from 98 to 70 per cent on the older nymphs. Thus, as may be seen from table 9, it would appear

Table 9.—**A tabulation of nine lindane and benzene hexachloride field experiments showing the control of the nymph of the meadow spittlebug during 1950 with various formulations and concentrations of the toxicants.**[1]

DATE	TYPE OF APPLICATION	TOXICANT IN Lbs./ ACRE	MASSES SQ. YD./ PLOT	PER CENT REDUCTION[2]
		Experiment 1		
April 18	dust (p)[3]	1.00	31.7	28.6
April 25	dust (p)	1.00	23.5	47.1
May 2	dust (p)	1.00	14.9	66.4
May 9	dust (p)	1.00	3.0	93.2
	none	—	44.4	—
		Experiment 2		
May 10	spray	0.10	1.0	98.0
	spray	0.20	0.0	100.0
	spray	0.30	0.0	100.0
	spray	0.40	0.0	100.0
	spray	0.50	0.0	100.0
	none	—	50.0	—
		Experiment 3		
May 16	spray	0.10	6.0	83.4
	spray	0.20	2.3	93.6
	spray	0.30	1.0	97.2
	spray	0.40	0.6	98.4
	spray	0.50	0.0	100.0
	none	—	36.3	—
	dust (p)	1.00	2.9	94.4
		Experiment 4		
May 17	spray	0.05	1.0	97.2
	spray	0.10	0.6	98.4
	spray	0.15	0.0	100.0
	none	—	36.0	—
		Experiment 5		
May 23	dust	0.35	5.3	68.4
	dust	0.50	2.6	84.5
	dust	0.75	3.0	82.7
	dust (p)	1.00	3.4	92.3
	dust	1.25	0.1	99.4
	none	—	16.8	—
		Experiment 6		
May 24	spray	0.05	5.6	91.1
	spray	0.10	1.3	97.9
	spray	0.15	0.6	99.0
	none	—	63.3	—
		Experiment 7		
May 31	spray	0.05	7.0	80.5
	spray	0.10	2.3	93.6
	spray	0.15	1.0	97.2
	none	—	36.0	—
		Experiment 8		
June 2	dust	0.35	4.6	81.6
	dust	0.50	3.0	88.0
	dust	0.65	0.8	96.8
	dust	0.75	2.1	91.6
	none	—	25.0	—
		Experiment 9		
June 7	spray	0.10	11.6	70.4
	spray	0.20	1.0	97.5
	spray	0.30	0.0	100.0
	none	—	39.3	—

[1] All treatments were applied on a single first crop year red clover field 19 acres in size with the exception of May 31 and June 2 treatments which were applied on a second crop year of red clover 100 yards distant from the first field, and the sprays applied June 7 which were applied to an alfalfa field.

[2] Counts were made 3 weeks after treatment from May 10 through May 31, June 2 and June 7 counts were made 2 weeks after treatment while the first series of dusts applied were checked 7, 6, 5, and 4 weeks after treatment respectively.

[3] (p) a timing experiment.

that in order to secure a near perfect control on any stage of the nymph, a spray concentration of at least 0.30 pound of actual gamma isomer benzene hexachloride should be applied per acre. Dusts applied on the same field, one day before the spray applications showed that at least twice the concentration of toxicant is required as a dust to achieve the same degree of effectiveness given by a spray application. The dusts applied on May 23 gave poorer control than those applied June 2 because the stand of red clover in the earlier treated field was much thicker and taller than in the latter field. As a result the applications of dust with the fertilizer distributors were more difficult and the poorer coverage gave inferior results.

SUMMARY AND CONCLUSIONS.—In the many field trials conducted during the past three years on alfalfa and red clover for the control of the meadow spittlebug, several insecticides and several methods of application were tested.

Of the three methods of application, the results have shown that low pressure spray equipment was the most effective method of control on forage crops, while thermal aerosols were usually too dependent upon climatic conditions to be of practical use on forage crops.

Benzene hexachloride and dieldrin, the former having a slight superiority at lower concentrations, were the most effective insecticides tested for the control of the meadow spittlebug. Toxaphene, methoxychlor, chlordane and heptachlor gave good control while aldrin and parathion were considered less satisfactory because of their poorer immediate kill and shorter residual action.

Near perfect control was achieved throughout the nymphal development in the life cycle of the meadow spittlebug with a spray concentration of 0.30 pound of actual gamma isomer benzene hexachloride per acre.

If spittlebug applications are made at the earliest possible date in order that weathering may reduce harmful residues at harvest, these applications should not be made any sooner than 1 week before the expected spittlebug emergence. Earlier applications did not give the control desired.

Field Trials in Onion Thrips Control

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The onion thrips, *Thrips tabaci* Lind., has long been considered as a pest by the onion growers of New York but during many years the infestations are low and occur so late in the season that control measures were unprofitable. This was the appraisal of Ewart *et al.* (1944) and Ashdown & Watkins (1948) from recent experiments. During years of low infestations their field research showed onion yields were not appreciably increased by a reduction of the onion thrips population.

Since 1944 (Annand *et al.*) DDT has been considered as one of the best insecticides for onion thrips control. This insecticide was found to hold onion thrips populations in check better than did tartar emetic or nicotine sulphate, materials formerly recommended. An important attribute of DDT has been its residual effectiveness. In this respect workers have generally found that its effectiveness is maintained for 1 week, as reported in papers by Bourne (1949), Chapman *et al.* (1945) (1947), Sleesman (1946), Wilcox & Howland (1948) and others.

Within the last 4 years many of the newer insecticides have been tested for control of onion thrips. Armand (1948) reported that under Canadian conditions chlordane sprays and dusts were more effective than DDT. Bourne (1949) found from spray tests that ryania reduced thrips infestation from 90 to 95 per cent immediately following application and that DDT gave perfect control. Although no mention is made of the immediate effect of parathion and chlordane sprays it was found that DDT and chlordane held the thrips population to a minimum while there was a build-up in the parathion plat. In dust experiments it was observed that DDT, parathion, and ryania gave high immediate kills but after 1 week chlordane and ryania had lost their effectiveness. Chapman *et al.* (1947) reported that benzene hexachloride applied as a dust gave control equal to DDT, either as a dust or spray. Douglas & Shirck (1949) noted some promising results with sprays containing benzene hexachloride, chlordane, toxaphene, and a mixture of DDT and hexaethyl tetraphosphate. Hoerner & Edmundson (1947) found that a benzene hexachloride spray did not reduce onion thrips populations as much as a DDT-sulphur dust but gave the same yield. Reed (1949) reported parathion to be a promising insecticide for onion thrips control in New Jersey. Shirck *et al.* (1949) obtained good results with sprays and dusts containing benzene hexachloride, chlordane, toxaphene, DDT and parathion. They found that sprays containing benzene hexachloride, chlordane, toxaphene and parathion in suspensions and DDT as an emulsion were more effective than those suspensions containing either technically pure gamma isomer of benzene hexachloride, DDT or tartar emetic. They also noticed that although parathion gave a high initial kill it did not protect the plants as well as DDT. The same workers found no significant difference in the effectiveness of chlordane, toxaphene or DDT emulsion sprays but that dusts containing benzene hexachloride, chlordane, toxaphene and parathion were significantly better than a DDT dust. Wene & Mayeux (1949) obtained better onion thrips control with dusts containing either toxaphene, benzene hexachloride, or a mixture of chlordane and DDT than with a mixture of DDT and benzene hexachloride. Wilcox & Howland (1950) reported toxaphene, parathion, aldrin, chlordane, benzene hexachloride and lindane to be more effective than DDT, TDE, and methoxychlor, when these materials were used in dusts.

During the summer of 1949 a drought prevailed over most of New York state. The above normal temperature and low rainfall made conditions ideal for a high onion thrips infestation. Early reports received from growers indicated that DDT was not furnishing satisfactory control unless it was applied at very frequent intervals. Due to the apparent failure of DDT to control the onion thrips under the conditions prevailing in 1949, a series of spray and dust experiments were started in Oswego and Wayne counties in an attempt to find a more satisfactory insecticide. These tests were continued

[1] The authors wish to acknowledge the assistance of Mr. Stefen Taraskiewicz in the project here reported.

during the growing season of 1950. The primary purpose of all experiments was to determine the length of the residual effectiveness of several of the newer organic insecticides and to compare them with DDT.

PROCEDURE.—Small scale experiments consisted of a series of one-hundredth acre plots with each treatment being replicated two to four times in randomized blocks. Large sized plots were used for aircraft applications and for applications with a sprayer mounted on a garden tractor. The latter equipment was similar to the type used commercially by the growers. The large plots were approximately one-half acre in size, usually consisting of one half of an onion bed; thus only two materials were compared on one onion bed but replications were obtained by using two or three beds for each experiment.

The small plots were treated with either a pack sprayer or a rotary hand duster, the dust applications being made at the rate of 40 to 45 pounds of dust per acre. In the Wayne county experiments sprays were applied at the rate of 75 to 100 gallons per acre using two fan type nozzles per row. Hollow cone spray nozzles[1] which delivered at the rate of 50 gallons per acre were used in the Oswego county experiments. The nozzles were so arranged on the hand spray boom that the operator was able to spray both sides of a single row in 1 operation.

The small garden tractor sprayer carried a four-row boom with two nozzles[1] for each row. The applications with this sprayer were applied at 55 to 60 pounds pressure using 40 to 45 gallons of spray per acre. Aircraft applications were made at rates of 35 to 40 pounds of dust or 3 gallons of concentrated spray per acre.

Only one application of the different insecticides was made in each experiment. The residual effectiveness of the treatments was determined by checking the onion thrips infestation at various intervals after the single application. The onion thrips populations in all experiments throughout both seasons were determined by counting the number of onion thrips on 10 to 30 onion plants chosen at random from the center rows of each plot. The number of plants counted varied with the size of the plot.

EXPERIMENTS IN 1949.—In a dust experiment two trials using several formulations of dust, some at different concentrations were conducted on seed onion fields in Oswego county. The concentrations used and the results of the experiment are given in table 1. The table indicates a relatively low onion thrips population within the treated area; however, it was continually observed in all experiments throughout both seasons that the check plots did not show as high an infestation as the onions surrounding the experimental area. This fact is clearly shown in tables 7 and 8 from other experiments where infestations in the check plots were compared with the onion thrips population on onions outside the experimental area. Also, as might be expected due to onion thrips migration within or among small plots, the results obtained from the different insecticides did vary between the dates of the infestation counts but they did follow a definite trend so their value in onion thrips control could be ascertained.

Two days after the application of insecticides in trial No. 1 it was found that heptachlor and aldrin gave better control than did DDT, chlordane, parathion or lindane. Ten days after the application the higher concentrations of heptachlor still gave fair control while DDT, parathion, lindane, chlordane, and a lower concentration of heptachlor gave less than 25 per cent control. For unexplainable reasons parathion was inferior throughout this experiment.

In trial No. 2 the infestation count made 2 days after application showed chlordane, heptachlor, aldrin, dieldrin, and parathion to be superior to DDT. A week later the higher concentrations of heptachlor dust showed over 50 per cent reduction of the onion thrips population.

The spray experiments during the season of 1949 were conducted on the muckland area in Wayne county. The onion thrips infestation in this region was exceedingly high and was without a doubt much worse than that encountered in Oswego county.

In one experiment various wettable powders and a DDT emulsion were tested in duplicate. The results as recorded in table 2 showed that chlordane, parathion,

[1] Teejet No. 6.

Table 1.—Onion thrips populations per plant and per cent reduction in plots treated with various dust formulations, Oswego County, N. Y., 1949.

Treatment	Days After Application							
	2		4		7		10	
	No. Thrips	% Red.	No. Thrips	% Red.	No. Thrips	% Red.	No. Thrips	% Red.
Trial 1[1]								
Chlordane 3%	3.2	68	5.8	16			8.1	16
Heptachlor 1%	4.4	56	6.3	9			11.0	—
Heptachlor 3%	1.3	87	1.2	82			4.0	57
Heptachlor 5%	2.0	80	6.3	9			2.4	75
Aldrin 1%	3.6	64	6.5	6			4.5	53
Aldrin 3%	3.1	69	4.4	36			6.9	28
Aldrin 5%	2.3	77	2.2	68			6.2	35
DDT 5%	3.0	70	6.1	12			9.2	4
Parathion 1%	7.7	23	4.4	36			8.2	16
Lindane 1%	6.5	35	5.7	17			13.0	—
Check	10.0		6.9				9.6	
Trial 2[2]								
Chlordane 3%	1.8	67			7.3	32		
Heptachlor 1%	2.9	47			9.5	11		
Heptachlor 3%	1.1	80			5.3	50		
Heptachlor 5%	0.3	94			3.5	67		
Dieldrin 5%	0.5	91			7.9	26		
Aldrin 3%	3.0	45			7.8	27		
Aldrin 5%	1.3	76			7.0	35		
DDT 5%	2.2	60			15.4	—		
Parathion 1%	1.2	78			9.3	13		
Check	5.5				10.7			

[1] Application date July 11.
[2] Application date July 25.

aldrin, dieldrin and heptachlor were superior to lindane and DDT 2 days after application. Nine days following application dieldrin and heptachlor still maintained a reduction of 90 per cent or more. Parathion was observed to give a high initial kill but soon lost its effectiveness and although lindane gave poor control at the time of the 2-day count it showed a relatively low onion thrips population at the time of the 9-day count.

In another experiment 0.5, 1, and 2 pound concentrations of the active ingredient of aldrin, dieldrin and heptachlor were tested as well as 2-pound concentrations of chlordane and DDT, and 0.15 pound of parathion. Each treatment was replicated three times. Onion thrips infestation counts, as given in table 3, were taken 2 and 13 days after the single application.

At the time of the 2-day population count all treatments were found to give highly significant reductions in the onion thrips population. Also the initial kill obtained with the two higher concentrations of dieldrin and the highest concentration of heptachlor were significantly better than DDT. The residual action of dieldrin and heptachlor was still in evidence 13 days after application. It might be worthy to note that although chlordane, parathion and DDT gave fair to good control

Table 2.—Onion thrips populations per plant and per cent reduction in plots treated with various wettable powders and a DDT emulsion, Wayne County, N. Y., 1949.

Treatment[1]	Days After Application			
	2		9	
	No. Thrips	% Red.	No. Thrips	% Red.
DDT—2 lbs.	18.8	76	14.5	80
Chlordane—2 lbs.	6.9	91	19.9	73
Parathion—0.3 lb.	3.1	96	30.1	59
Lindane—0.5 lb.	52.0	33	11.1	85
Aldrin—2 lbs.	13.0	98	11.7	84
Dieldrin—2 lbs.	17.0	98	4.2	94
Heptachlor—2 lbs.	0.6	99	4.4	94
DDT (emulsion) —0.5 lb.	8.7	88	14.1	80
Check	78.3		73.1	

[1] Amount of actual insecticide per acre; application date, June 30.

at the time of the 2-day count, they had lost their effectiveness after 13 days.

An experiment was designed to determine whether there was any difference in the degree of control obtained between the emulsion and wettable powder formulations of the same insecticide. The plots for this experiment were replicated four times but only one infestation count was taken 2 days after the single application. The materials tested and the results of this experiment are given in table 4.

At the time of the infestation count all treatments were highly significant over the check. Chlordane, heptachlor, aldrin and dieldrin gave better control than did DDT. Little apparent advantage could be found for either the emulsion or the wettable powder formulation, as far as one being better than the other; however, to determine definitely this problem infestation counts should be taken at longer intervals of time after the date of application.

EXPERIMENTS IN 1950.—Although the onion thrips infestation in 1950 was, in general, less severe than that encountered in 1949, it was heavy enough in certain locations of the state to be of economic importance and the opportunity did arise for further experimental work on onion thrips control. The experiments conducted in 1950 were mainlycomparison studies on large plots; however, two small plot spray experiments were also conducted further to check the effectiveness of the newer insecticides.

Since DDT, as an emulsion type spray or as a dust, was the insecticide that was most extensively used by the growers, it was relatively easy to compare the effectiveness of this material with similar formulations of dieldrin. In the first experiment dieldrin was compared with DDT on two different farms (designated as trials 1 and 2 in table 5). On each farm two 1-acre beds of seed onions were divided into equal parts so that all beds were sprayed with both insecticides. The single spray application was made with a spray rig mounted on a garden tractor. Untreated check areas were not used in this experiment but instead direct comparisons were made on the residual effectiveness of dieldrin and DDT.

The results of the spray comparison

Table 3.—Onion thrips populations per plant and per cent reduction in plots treated with various concentrations of wettable powder sprays, Wayne County, N. Y., 1949.

TREATMENT[1]	DAYS AFTER APPLICATION			
	2		13	
	No. Thrips	% Red.	No. Thrips	% Red.
Chlordane—2 lbs.	3.9	90	20.3	—
Parathion—0.15 lb.	4.3	89	16.8	—
DDT—2 lbs.	10.4	73	15.7	6
Aldrin—8 oz.	8.8	78	14.7	12
Aldrin—1 lb.	6.5	84	10.8	35
Aldrin—2 lbs.	3.8	90	4.3	74
Dieldrin—8 oz.	3.3	92	5.2	69
Dieldrin—1 lb.	0.4	99	0.6	96
Dieldrin—2 lbs.	1.2	96	1.2	93
Haptachlor—8 oz.	2.6	93	3.5	79
Heptachlor—1 lb.	1.5	96	4.1	75
Heptachlor—2 lbs.	0.6	98	2.7	84
Check	39.9		16.7	
Difference for significance (odds 19:1	9.0		not sig.	
Difference for significance (odds 99:1)	12.3		not sig.	

[1] Amount of actual insecticide per acre; application date, July 6.

Table 4.—Onion thrips populations per plant and per cent reduction in an experiment comparing the effectiveness of emulsion and wettable powder formulations of various insecticides, Wayne County, N. Y., 1949.

TREATMENT[1]	2 DAYS AFTER APPLICATION	
	No. Thrips	% Red.
0.5 lb. actual insecticide per acre		
DDT emulsion	8.5	78
DDT wettable powder	12.6	68
Chlordane emulsion	1.1	97
Chlordane wettable powder	1.8	95
Aldrin emulsion	2.0	95
Aldrin wettable powder	2.7	93
Dieldrin emulsion	1.0	97
Dieldrin wettable powder	0.6	98
Heptachlor emulsion	0.9	98
Heptachlor wettable powder	0.9	98
Check	39.2	
Difference for significance (odds of 19:1)	14.1	
Difference for significance (odds of 99:1)	18.9	

[1] Application date, July 14.

experiment are given in table 5. In the first trial the dieldrin plots showed above a 90 per cent reduction over the DDT plots 2 days after the application. This reduction decreased at the time of the 5 and 7 day counts but increased to 70 per cent after 10 days. Similar results were obtained in trial 2. This experiment pointed out that dieldrin not only gave a higher initial kill but also definitely had a longer residual effect.

In an aircraft application experiment DDT and dieldrin were tested first as dusts and later as emulsion type sprays. To compare the effectiveness of the individual dusts or emulsion sprays three 1-acre beds of seed onions were used. The spray formulations were applied to the same three beds 26 days after the application of the dust formulations, and as in the preceding experiment no untreated check plots were used. For both applications, each 1-acre bed was divided into two equal parts so that there were three replicates of either insecticide treatment; however, the section of each bed that was dusted with DDT later received a spray application of dieldrin. This procedure actually gave the dieldrin plots a disadvantage because of the higher onion thrips population in the former DDT dust plots and of course gave the DDT spray an advantage for the opposite reason.

For the dust comparison equal concentrations of DDT and dieldrin were applied in mid-July. The counts revealed that the onion thrips population was at least 60 per cent lower in the dieldrin treated plots for 10 days and 29 per cent lower 22 days after application.

Table 5.—Onion thrips populations per plant in an experiment comparing DDT and dieldrin emulsion sprays applied with ground equipment to large plots, Oswego County, N. Y., 1950.

	Days After Application				
	2	5	7	10	12
Treatment[1]	Thrips	Thrips	Thrips	Thrips	Thrips
Trial 1[2]					
Dieldrin—0.96 lb.	0.3	2.9	5.3	3.7	
DDT—1 lb.	3.6	4.5	10.7	12.5	
Trial 2[3]					
Dieldrin—0.96 lb.		0.9			2.4
DDT—1 lb.		1.8			7.7

[1] Amount of actual insecticide per acre.
[2] Application date July 3.
[3] Application date July 1.

The sprays were applied when the infestation in the dust plots had built up to a high number of onion thrips per plant. In this part of the experiment a dieldrin emulsion spray was compared with a combination DDT-tetraethyl pyrophosphate spray. Infestation counts showed a 66 per cent lower population in the dieldrin plots 3 days after application; however, at the time of the 8-day count the reduction was only 29 per cent in favor of the dieldrin emulsion. The reason for the lower efficiency of the dieldrin emulsion in comparison to the preceding dust application may have been due to the maturity of the onions; at the time of the 8-day count many of the onions had wilted, thus increasing the amount of thrips migration.

During 1950 small plot spray experiments were conducted in Oswego and Wayne counties. In Oswego county several emulsion sprays were tested as well as wettable powders. Infestation counts were taken at various intervals after

Table 6.—Onion thrips populations per plant in an experiment comparing the effectiveness of DDT and dieldrin dusts and sprays applied by aircraft to large plots, Oswego County, N. Y., 1950.

	Days After Application					
	3	5	7	8	10	22
Treatment	Thrips	Thrips	Thrips	Thrips	Thrips	Thrips
Dust Application[1]						
Dieldrin 5%	2.5	3.2	4.2		5.3	45.6
DDT 5%	7.8	8.1	10.5		20.6	64.5
Spray Application[2]						
Dieldrin (1 qt. 24% emul.)	6.5			39.3		
DDT—(1 qt. 25% emul. and 8 fl. oz. 40% tetraethyl pyrophosphate	19.2			55.6		

[1] Applied with a Piper Cub on July 19.
[2] Applied with a Steerman on Aug. 10.

Table 7.—Onion thrips populations per plant and per cent reduction in plots treated with various emulsion and wettable powder sprays, Oswego County, N. Y., 1950.

TREATMENT[1]	DAYS AFTER APPLICATION									
	3		6		8		10		15	
	Thrips	Red.	Thrips	Red.	Thrips	Red.	Thrips	Red.	Thrips	Red.
Test Material No. 1[2] (w.p.)—0.135 lb.	7.3	67	7.2	60	18.5	46	24.8	17	49.8	—
DDT (emul.)—1 lb.	9.2	60	5.5	69	9.9	71	14.3	52	25.8	40
Parathion (w.p.)—0.075 lb.	5.6	75	8.2	54	26.0	21	28.5	4	37.7	13
Aldrin (emul.)—0.92 lb.	1.6	93	1.6	91	3.9	89	4.3	86	11.8	73
Dieldrin (emul.)—0.96 lb.	0.7	97	1.1	94	2.8	92	3.5	88	6.9	84
Check	22.7		18.0		34.2		29.8		43.2	
Diff. required for sig. (odds 19.1)	4.3		4.7		7.1		5.8		13.3	
Diff. required for sig. (odds 99.1)	6.1		6.7		10.1		6.8		19.0	
Thrips count outside plot area	42.5		34.0		60.0		57.5		65.0	

[1] Amount of actual insecticide per acre; application date, July 19.
[2] Ethyl *p*-nitrophenyl thionobenzenephosphate.

application and the results of these counts, as well as the insecticide concentrations, are given in table 7.

It was found that all materials gave significant control for 8 days but at the time of the 10-day infestation count Test Material No. 1, and parathion were not significantly better than the check. Aldrin and dieldrin showed a higher degree of control throughout the experiment and 15 days after application they gave significantly better control than DDT, Test Material No. 1, and parathion.

A similar spray experiment was conducted in Wayne county and the concentrations used as well as the results are given in table 8. The infestation counts revealed that all treatments gave significant control for 3 days: however, 16 days after application only dieldrin, heptachlor, parathion and the higher concentrations of Test Material[2] were found to be significantly better than the check. The DDT plots, at the time of the final count, had an infestation higher than the check.

SUMMARY.—Experiments for the con-

Table 8.—Onion thrips populations per plant and per cent reduction in plots treated with various emulsions and wettable powder sprays. Wayne County, N. Y., 1950.

TREATMENT[1]	3 Days		7 Days		16 Days	
	Thrips (No.)	Reduction (%)	Thrips (No.)	Reduction (%)	Thrips (No.)	Reduction (%)
DDT—2 lbs.	21.7	31	2.5	86	36.2	—
Parathion—0.45 lb.	8.6	76	3.8	78	18.7	43
Dieldrin—1 lb.	6.2	83	1.8	90	10.2	69
Heptachlor 1 lb.	6.8	81	2.2	87	6.0	82
Test Material 1[2]						
0.27 lb.	15.4	58	5.8	67	17.7	46
0.54 lb.	17.1	53	11.8	33	25.5	23
Test Material 2[3]						
1 lb.	19.8	45	6.8	61	25.0	24
3 lbs.	21.9	40	9.3	47	17.4	47
Check	36.5		17.5		32.9	
Difference required for significance						
Odds 19-1	13.2		Not Sig.		13.0	
Odds 99-1	18.2				18.0	
Thrips count outside plot area	40.7		19.6		52.8	

[1] Amount of actual insecticide per acre. Application date, August 5.
[2] Ethyl p-nitrophenyl thionobenzenephosphonate.
[3] Bis dimethylaminophosphonous anhydride.

trol of onion thrips were conducted with several of the newer insecticides on fields of seed onions in New York in 1949 and 1950 when it was found that DDT was not giving the degree of commercial control that the growers desired.

In an experiment conducted in 1949 to test various insecticide dusts, some in different concentrations, it was found that 3 and 5 per cent heptachlor and 5 per cent dieldrin gave a high initial kill and that heptachlor maintained above a 50 per cent reduction in the onion thrips population for 10 days. Concentrations of 5 per cent aldrin and 1 per cent parathion gave better than 75 per cent control 2 days after application but were only slightly effective, as were the other materials tested, 7 to 10 days later.

A test comparing various wettable powders and a DDT emulsion spray showed that aldrin, chlordane, dieldrin, heptachlor, and parathion gave 90 per cent control 2 days after application. Dieldrin and heptachlor still showed this high degree of control 9 days after application.

In another experiment three concentrations of aldrin, dieldrin, and heptachlor were tested as well as single concentrations of chlordane, DDT, and parathion. Two days after application all three concentrations of dieldrin and heptachlor and 2 pounds of chlordane and aldrin reduced the onion thrips population by 90 per cent or above. This high percentage of control was maintained by the 1 and 2-pound concentrations of dieldrin 13 days after application while parathion, chlordane, and DDT were ineffective.

An experiment comparing the emulsion and wettable powder formulation of aldrin, chlordane, DDT, dieldrin, and heptachlor indicated that all treatments were highly significant over the check 2 days after application. At this time little or no advantage could be found for an emulsion formulation over a wettable powder formulation.

In 1950, when comparing DDT and dieldrin emulsion type sprays applied with ground equipment it was found that dieldrin was much more effective than DDT and showed a 70 per cent lower onion thrips infestation 10 to 12 days after application.

Aircraft application of DDT and dieldrin dusts and sprays indicated that for 10 days 5 per cent dieldrin dust was at least 60 per cent more effective than a 5 per cent DDT dust. Twenty-two days after the single application the dieldrin plots still maintained a 29 per cent lower infestation. Also in an aircraft trial dieldrin emulsion spray was found to be more effective than a combination DDT-tetraethyl pyrophosphate spray for at least 8 days.

In a small plot spray experiment aldrin, DDT and dieldrin emulsions and Test Material 1 and parathion wettable powders were found to give significant control for 8 days. Fifteen days after application aldrin and dieldrin were significantly better than DDT, Test Material 1 and parathion.

Another spray test indicated good control for at least 3 days with DDT, dieldrin, heptachlor and Test Materials 1 and 2; again dieldrin and heptachlor were observed to give the highest degree of control for 16 days.

LITERATURE CITED

Annand, P. N. *et al.* 1944. Tests conducted by the Bureau of Entomology and Plant Quarantine to appraise the usefulness of DDT as an insecticide. JOUR. ECON. ENT. **37**(1): 125–59.

Armand, J. E. 1948. The onion thrips (Thrips tabaci). Canad. Sci. Div. Ent. Processed P. 106.

Ashdown, Donald, and T. C. Watkins. 1948. Field studies on control of onion thrips in New York. JOUR. ECON. ENT. **41**(3): 378–82.

Bourne, A. I. 1949. Control of onion thrips. *In* Mass. Agr. Expt. Sta. Ann. Rpt. 1948–49: 42–3.

Chapman, A. J., L. C. Fife, and R. L. McGarr. 1945. DDT for control of the onion thrips. JOUR. ECON. ENT. **38**(5): 608–9.

Chapman, A. J., C. A. Richmond, and L. C. Fife. 1947. Comparative toxicity of benzene hexachloride and DDT to thrips on cotton and onions. JOUR. ECON. ENT. **40**(4): 575–6.

Douglass, J. R., and F. H. Shirck. 1949. Experiments for control of onion thrips. JOUR. ECON. ENT. **42**(1): 68–72.

Ewart, W. H., T. C. Watkins and Donald Ashdown. 1944. Insecticidal uses of tartar emetic against onion thrips in New York. JOUR. ECON. ENT. **37**(2): 269–76.

Hoerner, J. L., and W. C. Edmundson. 1947. DDT and other treatments for control of onion thrips. JOUR. ECON. ENT. **40**(4): 603–5.

Reed, J. P. 1949. In N. J. Agr. Expt. Sta, Ann. Rpt. 1948–49: 30.

Shirck, F. H., J. R. Douglass, and H. C. Manis. 1949. In Idaho Agr. Expt. Sta. Ann. Rpt. 1948–49: 49
Sleesman, J. P. 1946. DDT for the control of onion thrips. Ohio Agr. Expt. Sta. Bimonthy Bul., 31(239): 39–40.
Wene, G. P., and H. S. Mayeux. 1949. Control of onion thrips in the lower Rio Grande Valley. Texas Agr. Expt. Sta. Prog. Rpt. 1176.
Wilcox, J., and A. F. Howland. 1948. DDT dust for control of onion thrips. JOUR. ECON. ENT. 41(5): 694–700.
Wilcox, J., and A. F. Howland. 1950. New insecticides for control of onion thrips in southern California. JOUR. ECON. ENT. 43(5): 690–3.

Orchard Mite Studies in 1950[1]

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In a previous paper, Chapman & Lienk (1950) mentioned that of the four species of tetranychid mites known to occur in western New York, only the two-spotted spider mite, *Tetranychus bimaculatus* Harvey, and the European red mite, *Paratetranychus pilosus* (C. & F.) were of general economic importance. Fundamentally, this is still correct; however, the authors have observed minor infestations of a newly described species, *Septanychus canadensis* McGregor (McGregor 1950), in three western New York localities.

In all instances *Septanychus canadensis*, for which we propose the name of four-spotted spider mite, was found on apple and in combination with either the two-spotted spider mite, European red mite or both species. It has also been collected in large numbers in at least one apple orchard near Peru, N. Y. in an apparently pure culture. The four-spotted spider mite infestation in this orchard was so severe as to warrant the use of an acaricide. Due to the morphological and biological similarities of *T. bimaculatus* and *S. canadensis*, it is almost certain that the distribution and consequent economic importance of *S. canadensis* is more widespread than our records indicate. The clover mite, *Bryobia praetiosa* Koch is prevalent throughout the state and according to our observations large populations are readily found in unsprayed orchards. It has, however, been reported to attain economic numbers in well kept orchards. The present report includes experiments only on the control of the European red mite and two-spotted spider mite.

Under conditions existing in western New York the European red mite attains peak activity in mid-summer. The two-spotted spider mite, however, first appears in numbers in fruit trees approximately a month later. This behavior was shown graphically by Chapman & Lienk (1950). Data obtained during the 1950 season confirm this general population pattern. This is believed to be the typical behavior in trees receiving no acaricidal treatments.

An important variation of this pattern, especially regarding the two-spotted spider mite, was demonstrated where treatments were used which nearly eliminated the European red mite population. Under these conditions the peak activity of the two-spotted spider mite occurred several weeks earlier and was maintained at a high level for a considerable period. These data will be published at a later date.

BIOLOGICAL.—Detailed studies were made in 1949 on the biology of two species of mites, namely, *Tetranychus bimaculatus* Harvey and *Paratetranychus pilosus* (C. & F.). This work was continued in 1950 and was expanded to include rearing work on *Septanychus canadensis* McG. and *Bryobia praetiosa* Koch. The general rate of development for *T. bimaculatus*, *P. pilosus* and *S. canadensis* was similar and approximately 8 generations developed. *B. praetiosa* develops at a slower rate and has only 5 generations. Furthermore, the habits of *B. praetiosa* are quite distinct. This species is likely to spend as much time on the spurwood and twigs as on the leaf itself, a habit not typical of the other species. Only parthenogenetic

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Table 1.—Efficiency of several acaricides against the winter eggs and newly hatched larvae of the European red mite. Host: apple, variety Wealthy. White Springs Farm. Geneva, N. Y., 1950.

Material and Rate per 100 Gallons	Rate of Application[1]	Date(s) Sprayed[2]	Indicated Initial Kill of Eggs	Number Hatched Mites per Leaf							
				6/22	7/3	7/13	7/26	8/3	8/15	8/29	9/20
TM-289[3] 1 qt.	standard	4/7	31.6%	5	5.7	32.9	50.8	182	80	2.4	1
TM-289[3] 1 qt.	excessive	4/7	47.6	3	1.5	16.3	40.9	135.2	74.2	5.2	2
TM-289[3] 2 qts.	standard	4/7	69.0	1.4	1.4	12.3	30.2	106.2	60.6	3.5	2
TM-289[3] 2 qts.	excessive	4/7	89.5	1	2.1	7.8	21.9	93.4	59	8.8	0
TM-289[3] 3 qts.	standard	4/7	93.4	1	0.9	6.2	16.3	69.4	31	7.5	1
TM-289[3] 3 qts.	excessive	4/7	96.8	0.2	0.2	1.6	11.5	26.8	64.6	12.6	1.2
Petroleum oil[4] 2 gals.	standard	5/4	98.3	0.08	0.04	0.16	1.2	8.8	30.4	15.0	0.8
Petroleum oil[4] 1 qt.	standard	5/4	—	0.7	0.4	3.3	7.3	15.3	37.1	14.5	0.3
TEPP[5] 8 fl. oz.	standard	5/16	—	0	0.04	0	0	1.2	0.3	6.2	4
TEPP[5] 8 fl. oz.	standard	5/16, 5/29	—	0	0	0	0.6	1.4	1.3	3.3	10
Petroleum oil[4] 1 gal.	standard	5/16	—	0	0	0.2	0.6	2	5.9	4.3	1.6
TM-1006[6] 1.5 lbs.	standard	5/17	—	0	0	0	0	0.6	0.4	3.5	5.6
TEPP[5] 8 fl. oz.	standard	5/29	—	0	0.4	0.2	1.2	7.2	5.1	9.2	0.8
Controls:				10	5	40	93	236	73	3	1

[1] Standard application rate denotes the amount of spray material necessary to thoroughly cover the trees. Excessive application rate is approximately twice the amount necessary for complete coverage.
[2] Bud stages on treatment dates were: 4/7 dormant; 5/4 delayed dormant; 5/16–17 pink; 5/29 calyx.
[4] A "superior" type dormant tree spray oil. For specifications see Journ. Econ. Ent. **42**: 45, 1949.
[5] Tetraethyl pyrophosphate (20%). California Spray Chemical Co.
[6] P-chlorophenyl p-chlorobenzene-sulfonate (50% W.P.). Dow Chemical Co.

reproduction has been observed during the summer; males, if they occur, appear perhaps only seasonally.

Ovicide Tests on Winter Eggs of the European Red Mite.—The results of recent tests with oil and dinitro compounds against winter eggs of the European red mite have been reported by Chapman & Pearce (1949) and Chapman & Lienk (1950). It was demonstrated that while dinitro ortho cresol was relatively ineffective, other dinitro materials, such as dinitro sec. butyl phenol and dinitro amyl phenol, were quite toxic to the eggs. In spite of the fact that a high initial kill of eggs was indicated with the two last named materials on the wood sampled, mite populations built up more rapidly on the dinitro plats compared with oil treated trees. It was thought that this contradiction in results might be accounted for on the grounds of differences in spray coverage properties between oil and dinitro sprays. In an attempt to clarify this situation the following experiment was set up. A product containing dinitro sec. butyl phenol was compared with a standard oil treatment. In one series of plats the dinitro material was applied in the usual manner as regards dosage per tree, namely, about 12 gallons spray per tree. This was considered a good commercial application for the rather small Wealthy apple trees used in the test. In a companion series each concentration of dinitro sec. butyl phenol was used at twice the normal gallonage. The weather conditions on the treatment dates were ideal for good coverage. The results obtained in this experiment are shown in table 1 and figure 1.

The "indicated initial kill of eggs" with dinitro sec. butyl phenol was lower than previously found, Chapman & Pearce (1949) and Chapman & Lienk (1950). The results with oil in the three years, however, were very similar. There was some increased efficiency obtained where the dinitro product was used at the higher volume. Development of mite populations in the various plats again demonstrated that the build-up was more rapid in the dinitro series than in the oil plat. Furthermore, the excessive spraying did not greatly improve the efficiency of the dinitro sec. butyl phenol. Unfortunately, the poorer results of "initial egg kill" obtained in 1950 with the dinitro material forecast the differences that subsequently developed. This was not the case in tests conducted in 1949. The results obtained

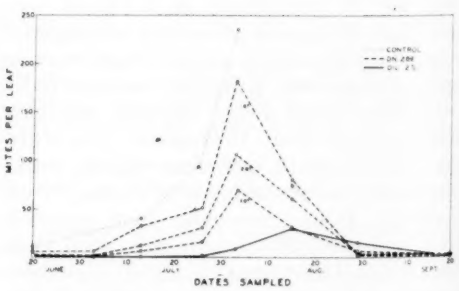

Fig. 1.—Record of the seasonal development of the European red mite in unsprayed trees and in plats treated with several concentrations of 21.5 per cent dinitro sec. butyl phenol and 2 per cent petroleum oil, 1950.

by New York fruit growers in 1950 with dinitro sec. butyl phenol generally confirm the experimental results reported here.

PRE- AND POST-BLOOM TREATMENTS AGAINST THE EUROPEAN RED MITE.—The hatching period of the winter eggs varies considerably in relation to the development of the host, but in 1950 there was a 50 per cent hatch of eggs prior to blossoming. The hatch was essentially complete at the end of bloom, and by this time the oldest females were nearly ready to deposit eggs for the new generation. This situtation would not permit any delay in applying calyx sprays especially if an acaricide is used that has little or no ovicidal action.

Several pre- and post-bloom sprays were tested and the results are given in table 1. While these tests are only of a preliminary nature, it is evident that the results were highly successful and warrant further trial. If such treatments prove dependable, there might be certain practical advantages to the grower in applying acaricides at this time rather than earlier. The pink and calyx treatments gave little or no control of the two-spotted spider mite which was present both on the trees and on the ground cover at this time.

Table 2.—Efficiency of several acaricides against the European red mite. Host: apple. George Aldrich orchard, North Rose, N. Y.

All materials applied July 9, 1950, as single treatments.

Material and Rate per 100 Gallons		Per Cent Reduction in Population				
		Days After July 9 Sprays				
		0	2–3	9–10	16	20
TM-2[1]	1 lb.	—	97.7	90.7	95.2	—
Parathion[2]	1 lb.	—	98.2	95.8	99.2	—
TM-4049[3]	20 oz.	—	97.4	90.5	96.0	—
TM-4124[4]	10 oz.	—	98.0	61.4	50.4	—
TM-4018[5]	10 oz.	—	95.5	91.9	95.2	—
TM-4[6]	8 oz.	—	95.7	79.0	79.5	—
TM-300[7]	8 oz.	—	97.0	100.0	100.0	—
TM-1007[8]	24 oz.	—	77.9	99.0	100.0	—
TM-5[9]	24 oz.	—	90.9	86.4	91.3	—
TM-242[10]	1 lb.	—	95.5	86.7	84.2	—
Dimite[11]	1 pt.	—	99.4	80.7	80.3	—
TM-1014[12]	2 qts.	—	98.2	89.8	91.3	—
		Average Number Mites per Leaf				
Controls:						
Hatched		204	308	236	127	96
Eggs		360	262	86	48	32

[1] Dinitro-capryl phenol-crotonate (25% W.P.) Rohm & Haas Co. = TM-1.
[2] 0,0-diethyl 0-p-nitro phenylthiophosphate (15% W.P.) American Cyanamid Co. = TM-4029.
[3] S-(1,2-Dicarbethoxyethyl) 0,0-dimethyl dithiophosphate (50% emul.) American Cyanamid Co. = TM-3.
[4] 0-(2-Chloro-4-Nitrophenyl) 0,0-dimethyl thiophosphate (25% emul.) American Cyanamid Co. = TM-C-1006.
[5] S-(1,2-Dicarbomethoxyethyl) 0,0-diethyl dithiophosphate (50% emul.) American Cyanamid Co.
[6] Diethyl-p-nitrophenyl-thiophosphate (33%, liq.) Geary Chemical Corp. = (TM-4).
[7] Ethyl p-nitrophenyl thionobenzenephosphonate (35% W.P.) E. I. du Pont de Nemours Co.
[8] TM-1014 P-chlorophenyl p-chlorobenzene-sulfonate (50% W.P.) Dow Chemical Co.
[9] TM-5 β chloroethyl (tert. butyl phenoxy) α methyl ethyl sulfite (15% W.P.) Naugatuck Chemical Div. *Aramite.*
[10] TM-242 P-chlorophenyl phenyl sulfonate (50% W.P.) Stauffer Chemical Co.
[11] TM-6 Di-(p-chlorophenyl) methyl carbinol (25%, liq.) Sherwin Williams Co.
[12] TM-1014 Bis(bis dimethylamino phosphonous) anhydride (66%, liq.) Dow Chemical Co.

SUMMER TESTS.—Evaluations were made of 16 materials, and in some cases of several formulations of these, for their possible acaricidal value against summer mite infestations. It was possible to conduct separate tests against essentially pure cultures of both the European red mite and the two-spotted spider mite. Experimental procedure and technique were the same as for the studies made in 1949, Chapman & Lienk (1950).

The materials tested and data obtained against the European red mite are given in table 2. A mature Northwestern Greening apple orchard was selected for the experimental block. Although the grower had applied a dinitro sec. butyl phenol treatment during the dormant period, a high population developed by early July. Attention is called to the fact that the population present throughout the test period was unusually high (Table 2). As in past years where new materials were under evaluation, single treatments have been used. The writers believe that such a procedure accurately reveals the potentialities of the material. Thus the 2 or 3 day count indicates the immediate effect of the acaricide. And since the incubation period of mite eggs in mid-summer is approximately of 7 to 9 day duration, the 10 or 11 day count shows the total effect, that is, immediate plus the ovicidal and residual action.

All the phosphorous containing materials exhibited good immediate kill; TM-300[1] at the concentration used gave the best residual action. Definite ovicidal action was detected in the plots treated with parathion, TM-300[1], and TM4049.[2] This was evident on the 2 or 3 day count where no newly hatched larvae, either dead or alive, were found. This was in contrast to all other treatments. It seems likely that the ovicidal action of the three

[1] Ethyl p-nitrophenyl thionobenzenephosphonate. (Test material TM-300.)
[2] S-(1,2-Dicarbethoxyethyl) 0,0-dimethyl dithiophosphate. (TM-4049.)

Table 3.—Efficiency of several acaricides against the two-spotted spider mite. Host: apple. White Springs Farm, Geneva, N. Y., 1950.

Series A Tests

Material and Amount per 100 Gallons		Date(s) Sprayed	Per Cent Reduction in Population			
			Days After First Treatment			
			2–3	10	21–22	31–32
Parathion[1]	8 oz.	8/11	80.4	86.4	64.4	0
Parathion[1]	8 oz.	8/11, 8/21	80.4	86.4	90.4	90.2
Parathion[1]	1 lb.	8/11	84.8	90.9	41.1	0
Parathion[1]	1 lb.	8/11, 8/21	84.8	90.9	98.6	96.7
TM-4049[2]	20 oz.	8/11	92.4	96.9	68.5	18.0
TM-4049[2]	20 oz.	8/11, 8/21	92.4	96.9	100.0	95.0
TM-7[3]	4 oz.	8/11	79.3	65.4	19.2	0
TM-7[3]	4 oz.	8/11, 8/21	79.3	65.4	94.5	91.8
TM-7[3]	8 oz.	8/11	80.4	85.7	39.7	0
TM-7[3]	8 oz.	8/11, 8/21	80.4	85.7	90.4	85.2
TM-6[4]	4 oz.	8/11	80.4	46.6	19.2	0
TM-6[4]	4 oz.	8/11, 8/21	80.4	46.6	72.6	72.0
TM-300[5]	4 oz.	8/11	78.3	96.2	54.8	14.6
TM-300[5]	4 oz.	8/11, 8/21	78.3	96.2	98.6	98.4
TM-5[6]	1 lb.	8/11	48.9	93.9	91.8	40.9
TM-5[6]	1 lb	8/11, 8/21	48.9	93.9	95.9	90.2
			Average Number Hatched Mites per Leaf			
Controls			92	133	73	61

Series B Tests

			Days After First Treatment			
			2	12	22	30
Parathion	1 lb.	8/16	96.2	86.8	76.2	58.4
Parathion	1 lb.	8/16, 8/28	96.2	86.8	96.4	98.7
Parathion	2 lbs.	8/16	95.3	72.8	76.2	64.9
Parathion	2 lbs.	8/16, 8/28	95.3	72.8	97.6	97.4
TM-4049[2]	2 lbs.	8/16	96.2	93.9	90.5	76.6
TM-4049[2]	2 lbs.	8/16, 8/28	96.2	93.9	98.8	100.0
TM-300[5]	8 oz.	8/16	94.3	97.4	92.9	81.8
TM-300[5]	8 oz.	8/16, 8/28	94.3	97.4	97.6	100.0
TM-8[7]	2 lbs.	8/16	75.5	92.1	95.2	87.0
TM-8[7]	2 lbs.	8/16, 8/28	75.5	92.1	98.8	93.5
TM-242[8]	2 lbs.	8/16	68.9	91.2	71.4	38.9
TM-242[8]	2 lbs.	8/16, 8/28	68.9	91.2	97.6	71.4
TEPP[9]	8 oz.	8/16	93.4	64.9	71.4	24.7
TEPP[9]	8 oz.	8/16, 8/28	93.4	64.9	88.0	79.2
TM-7[3]	16 oz.	8/16	89.6	65.8	26.2	49.4
TM-7	16 oz.	8/16, 8/28	89.6	65.8	89.3	93.5
TM-1006[10]	24 oz.	8/16	47.1	94.7	94.0	96.1
TM-1006[10]	24 oz.	8/16, 8/28	47.1	94.7	97.6	97.4
			Average Number Hatched Mites per Leaf			
Controls:			106	114	84	77

[1] American Cyanamid Co., 15 per cent.
[2] S-(1,2-Dicarbethoxyethyl) 0,0-dimethyl dithophosphate (25% W.P.) American Cyanamid Co.
[3] TM-7 Diothoxy thiophosphoric ester of 7-methyl-4-hydroxy coumarin (30% emul.) Geary Chemical Corp.
[4] TM-6 Diethyl-p-nitrophenyl-thiophosphate (33% liq.) Geary Chemical Corp.
[5] Ethyl p-nitrophenyl thionobenzenephosphonate (35% W.P.) E. I. duPont de Nemours Co.
[6] β chloroethyl (tert. butyl phenoxy) α methyl ethyl sulfite (15% W.P.) Naugatuck Chemical Division.
[7] TM-8 Dinitro-capryl phenol-crotonate (25% W.P.) Rhom & Haas Co.
[8] TM-428 P-chlorophenyl phenyl sulfonate (50% W.P.) Stauffer Chemical Co.
[9] Tetraethyl pyrophosphate (20% emul.) California Spray Chemical Co.
[10] P-chlorophenyl p-chlorobenzene-sulfonate (50% W.P.) Dow Chemical Co.

materials at the concentration used is limited to the older eggs. Results with TM-C-1014[1] are of interest because the material is rated as a systemic toxicant. Some leaf injury occurred from this single treatment. While there was little evidence of systemic action detected against the mites, observations made on the apple aphid, *Aphis pomi* DeG., which was prevalent in the test block, indicated that there was some systemic action against this species. No evidence of this action was noted up to 20 days but was strongly indicated 7 weeks after treatment. The TM-4 C-1006[2] gave the poorest immediate control but proved highly effective in the 10 and 16 day count. This is in line with results obtained in 1949 when it was tested under the code C-854 (TM C-1006).

The experiments conducted against the two-spotted spider mite are detailed in table 3. The test orchard consisted of apple trees of the variety Rome Beauty. Aside from the fact that the materials were evaluated as single and dual treatments, the procedures were identical with those described above for the European red mite tests. The second treatment was applied immediately after the 10 or 12 day count was made. The results obtained with these materials against the European red mite and the two-spotted spider mite were very similar through the 10 to 12 day counts. Protection was lost after this time in the case of the two-spotted spider mite with some materials as can be seen in the later counts. Of special interest is the result obtained with a single treatment of TM C-1006 which was the only material that gave full protection over a month's period, confirming again the experiences with this product in 1949.

GROUND COVER TREATMENTS.—As is well known, the two-spotted spider mite has a wide variety of hosts, including most of the plants that may comprise an orchard ground cover. The control of the species as an orchard pest is complicated by the possibility of reinfestation from the ground where treatment is limited to the tree. Various workers have considered the possibility of treating the ground cover, alone or in conjunction with tree treatments in a control program. It occurred to the writers that a systemic pesticide might have possibilities as a ground treatment in this situation. This would eliminate the need of completely covering these plants since many of them are closely appressed to the ground.

A preliminary test was conducted to explore the possibilities. A mature apple orchard of the Twenty Ounce variety was selected. While the ground cover in this block was variable, field bindweed (*Convolvulus arvensis* L.), a favorite host of the two-spotted spider mite, was present under many trees.

Only single tree plats were used in the experiment owing to the limited supply of test materials available. To overcome this experimental limitation great care was observed in selecting test trees so that these and mite populations present were as near as possible alike throughout. The ground cover under the trees was continuous and also extended between the rows; it consisted predominately of field bindweed.

At the time the test was initiated a heavy population of the two-spotted spider mite was present on the bindweed and a moderate mixed population of both the European red mite and two-spotted spider mite in the trees. To measure the full effects of the treatments it seemed desirable to attempt to eliminate the mite population in the trees. Consequently the trees in all plats except the complete control were first thoroughly sprayed with TM-300. The ground cover directly under the trees was not protected against run off of the TM-300 treatment. Within a short time after spraying the trees, the two systemic materials were applied to the ground cover under and for some distance beyond the spread of each tree. The trees in this orchard are planted 35 feet apart, and the spraying extended to the middle of the rows. Consequently approximately 1125 feet of surface under and surrounding each tree was treated in each instance. Details on the experiment and the results obtained are given in table 4.

The data indicate that the mite population on both ground cover and tree was heavy at the time of treatment. As shown in the control, this level remained high for several weeks, but 40 days after treatment it declined considerably. This is the normal seasonal decline. The mite population found in plat 3, 15 days after

[1] Bis (bis dimethylamino phosphonous) anhydride. (TM-C1014.)
[2] P-chlorophenyl p-chlorbenzene-sulfonate. (TM-C-1006.)

Table 4.—Ground cover treatment tests for the control of the two-spotted spider mite. Host: Twenty Ounce apple. White Springs Farm, Geneva, N. Y.

All treatments applied August 10, 1950

Plat No.	Tree or Ground Cover[1]	Treatment and Rate per 100 Gallons		Mites per Leaf Days After Treatment 15	26	40
1	Tree	TM-300[2]	8 oz.	—	4.5	11.2
	Ground cover	TM-C1014[3]	2 qts.	9.2	1.6	2.4
2	Tree	TM-300[2]	8 oz.	—	0.8	1.6
	Ground cover	TM-10[4]	2 qts.	0.8	0.5	0.0
3	Tree	TM-300[2]	8 oz.	—	47.0	60.0
	Ground cover	None		28.2	58.6	120.2
4	Tree	None		—	143.6	60.0
	Ground cover	None		304	199.6	100.0

[1] The ground cover under test trees was continuous and consisted primarily of field bindweed (*Convolvulus arvensis* L.).
[2] Ethyl p-nitrophenyl thionobenzenephosphonate (35% W.P.) E. I. du Pont de Nemours & Co.
[3] Bis (bis dimethylamino phosphonous) anhydride (66%, liq.) Dow Chemical Co.
[4] Tri alkyl thiophosphate (32.1%, liq.) Geary Chemical Corp. (TM-10.)

treatment on the ground cover, shows the degree of protection provided by the run off of TM-300[1]. As will be seen, the population attained essentially the same level as the control at the end of 40 days, both on the tree and ground cover. The combined action of the TM-300 tree treatment and the systemic ground cover sprays is clearly evident in plats 1 and 2. The fact that the mites in these plats did not attain the same level in the trees as those in plats 3 and 4 is attributed largely to systemic action.

SUMMARY AND CONCLUSIONS.—Of the four species of mites that occur in western New York apple orchards, the European red mite and the two-spotted spider mite are major pests. The writers propose the common name of four-spotted spider mite for the recently described species, *Septanychus canadensis* McGregor. This species closely resembles the two-spotted spider mite in habits and injury.

TM-289[2] (21.5 per cent dinitro sec. butyl phenol) at 0.25 per cent, 0.5 per cent, and 0.75 per cent proved inferior to a 2 per cent petroleum oil spray in killing winter eggs of the European red mite. The dinitro compound failed to equal the efficiency obtained with oil, even in plats where twice the normal gallonage of spray was applied.

Applications made just prior to bloom using tetraethyl pyrophosphate, 1 per cent petroleum oil, and p-chlorophenyl p-chlorobenzene-sulfonate gave excellent early season control of the European red mite. These treatments were superior to any of the winter ovicide sprays tested.

Sixteen materials were tested for their value in combatting summer infestations of the European red mite and the two-spotted spider mite. All of the organophosphorous compounds, of which there were eight, were highly effective in killing hatched forms of the mites. Residual action up to one month was attained from a single application of p-chlorophenyl p-chlorobenzene-sulfonate. Results indicate that two treatments, spaced 10 days apart, are necessary to achieve adequate control of the two-spotted spider mite with all materials tested except possibly p-chlorophenyl p-chlorobenzene-sulfonate. Theoretically, single treatments of parathion and ethyl p-nitrophenyl thionobenzenephosphonate will control a summer infestation of the European red mite. In commercial practice, however, dual treatments would probably be necessary.

In a preliminary test promising results were obtained in controlling the two-spotted spider mite through the use of two systemic phosphorous materials applied to the orchard ground cover.

[1] *DN-289.*
[2] Ethyl p-nitrophenyl thionobenzenephosphonate.

LITERATURE CITED

Chapman, P. J., and G. W. Pearce. 1949. Susceptibility of winter eggs of the European red mite to petroleum oils and dinitro compounds. JOUR. ECON. ENT. **42:** 44–7.

Chapman, P. J., and S. E. Lienk. 1950. Orchard mite control experiments in western New York. JOUR. ECON. ENT. **43:** 309–14.

McGregor, E. A. 1950. Mites of the family Tetranychidae. Amer. Mid. Nat. **44:** 257–420.

Relation Between Sugar Content of Corn and Infestation and Survival of the European Corn Borer

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The importance of sugar in nutrition of larvae of the European corn borer has been shown by Beck and Lilly (1949). They found that both survival and growth of larvae were benefited when young corn plants were cut and placed in sugar solution. Beck (1950) reported that larvae fed on an artificial diet without glucose failed to complete their development. In a study of field corn inbreds, Turner and Beard (1950) found an unusually high rate of survival of larvae hatching on C103, an inbred known to be high in sugar. These facts suggested a study of the effect of sugar content of growing corn on survival of the corn borer.

Beard (Beard & Turner 1942) and Beard (1943) has completed studies of the relation between stage of growth of corn and survival of the borer. Survival was very low until the plants reached the late whorl stage of growth as defined by Batchelder (1949). Any relation between stage of growth and sugar content was therefore of great interest.

METHODS.—Two hybrid sweet corns were selected for test during the first generation of the corn borer. Marcross is an early variety of fair quality. Washington is approximately in the same season, of better quality, and might be expected to contain more sugar. These two varieties were planted April 17 and May 9. The plots were randomized in five blocks, a plot being 2 rows of 10 plants each. Six feet of fallow ground separated the plots to minimize migration of larvae. Each plant was examined twice a week during oviposition; egg masses were tagged and their hatching noted. When the corn reached the roasting ear stage (July 20) the plants were dissected to determine the number of larvae surviving.

The sugar content of the plant sap was determined three times during the period when larvae were hatching. The amount of sugar was estimated by use of a portable refractometer. Sap was taken from the base of the plant.

One field corn inbred, C103; two single cross hybrid field corns, C103×Oh43 and Oh51A×Oh43 and a late sweet corn hybrid, Brookhaven, were included in the test on the second generation. Plots were the same size as the 1st generation planting. C103 was supposed to be high in sugar. Oh51A×Oh43 has been "resistant" to corn borer in tests in the Middle West. It was selected as a possible representative of low sugar content. C103×Oh43 was chosen as having a common parent with the "resistant" hybrid. Brookhaven was used because a sweet corn might be high in sugar.

Table 1.—Oviposition and survival of corn borers. First generation, 1950.

VARIETY	DATE PLANTED	EGG MASSES	LARVAE SURVIVING	SURVIVAL PER EGG MASS
Marcross	April 17	238	954	4.01
	May 9	176	540	3.06
Washington	April 17	110	402	3.65

RESULTS.—*First generation, sweet corn.*—Eggs were found on June 13, and a well-defined peak of oviposition occurred on June 26. Infestation was relatively low. The May 9 planting of Washington was dropped because it was too late in development to compare with either planting of Marcross.

The results are summarized in tables 1 and 2. The first planting of Marcross received more eggs, had more larvae and a higher rate of survival than the second planting or the planting of Washington. It had a lower sugar content than Washington. The difference in rate of survival is not significant statistically. Washington had a higher sugar content than Marcross throughout the period of larval development. The higher sugar content did not result in higher survival of larvae. There is also an implication that sugar content did not affect oviposition.

The May 9 planting of Marcross had a

Table 2.—Sugar content and stage of growth of sweet corn.

VARIETY	DATE PLANTED	MEAN PER CENT SUGAR			GROWTH STAGE	
		6/29	7/6	7/13	6/29	7/6
Marcross	April 17	2.6	2.5	3.4	T-1	T-3
	May 9			1.8		W-3
Washington	April 17	3.2	3.7	4.8	W-3	T-2

Table 3.—Oviposition and survival of corn borers on three field and one sweet corn, second generation, 1950.

Variety	Date Planted	Egg Masses	Larvae Surviving	Survival per Egg Mass
C-103	May 9	67	359	5.4
	May 23	103	398	3.9
Oh51A×Oh43	May 23	139	420	3.0
C103×Oh43	May 9	118	338	2.9
	May 23	208	524	2.5
Brookhaven	May 9	128	437	3.4
	May 23	205	729	3.6
	May 31	225	966	4.3

very low sugar content on July 31. It was slightly later than Washington. Survival was lower than in Washington but the difference was not significant statistically.

Second generation.—Eggs were found on August 7, and oviposition continued until August 30. There was no well-defined peak for all plots. Some plots did have a maximum oviposition on August 20. Infestation was very light, the most heavly infested variety had only 225 egg masses on 100 plants.

Results of the observations have been summarized in tables 3, 4, and 5. The May 9 planting of Oh51A×Oh43 was dropped from consideration because it had reached a late stage of growth when oviposition started.

Oviposition.—All varieties were at least in the attractive late whorl stage when oviposition started. The inbred C103 received fewer egg masses than any other variety. It was, of course, the smallest variety in the test. As was the case in the

Table 4.—Sugar content of corn during season of infestation by the corn borer.

Variety	Date Planted	Mean Per Cent Sugar 8/11	8/18 - 8/25	8/31	Average
C103	May 9	7.4	10.2	9.9	12.5	10.0
	May 23	4.8	7.3	9.6	11.9	8.4
Oh51A×Oh43	May 23	6.9	8.5	8.2	7.4	7.8
C103×Oh43	May 9	9.0	11.1	11.9	11.4	10.8
	May 23	6.2	9.4	10.5	11.0	9.3
Brookhaven	May 9	7.0	8.4	9.3	8.7	8.3
	May 23	5.6	7.6	8.0	8.0	7.3
	May 31	4.2	6.1	5.8	7.8	6.0

Table 5.—Growth stages of corn during oviposition period, second generation, 1950.

Variety	Date Planted	Growth Stage 8/7	8/16	8/23	9/1
C103	May 9	T-2	S-2	S-2	RE
	May 23	W-3	T-2	S-1	S-2
Oh51A×Oh43	May 23	S-1	S-2	S-3	RE+
C103×Oh43	May 9	S-1	S-2	S-3	RE
	May 23	T-2	S-2	S-2	S-3+
	May 31	W-3	T-2	S-1	S-2

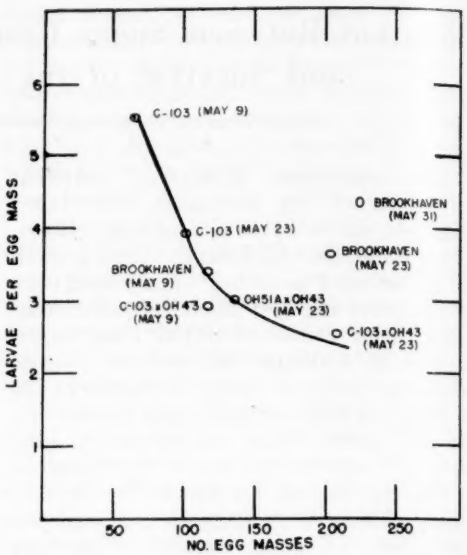

FIG. 1.—Relation between number of egg masses deposited and number of larvae per egg mass. Two plantings of Brookhaven deviated from the general pattern.

1949 test (Turner & Beard, 1950) more eggs were deposited on the younger plants. The sweet corn Brookhaven had an average of one tiller per plant, while there was only an occasional tiller on the field corn plants. Results of tests made in 1945 (Turner, 1945) indicated that plants with one tiller received about the same number of eggs as those with no tillers. Certainly the moths showed no decided preference for sweet corn over field corn.

Survival.—The rate of survival (Table 3) ranged from 2.5 larvae per egg mass on C103×Oh43 planted May 23 to 5.4 on C103 planted May 9. There seems to be no logical explanation for this abnormal rate for the May 9 planting of C103. It occurred in 1949 tests on the early planting, however (Turner & Beard, 1950).

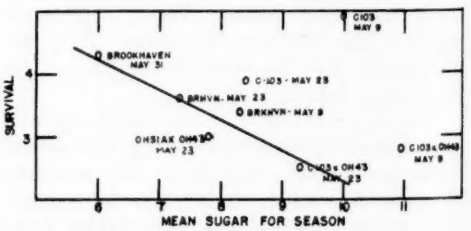

FIG. 2.—Relation between sugar content and survival of larvae of the European corn borer. Correlation is not clear-cut, even with the best possible fit of the curve.

The single cross C103×Oh43 did not show a similarly high survival. In contrast with the trend on field corn inbreds and hybrids, survival increased on the later plantings of the sweet corn Brookhaven.

All of the plots were in susceptible stages of growth (Beard, 1943) during infestation (Table 5). There were no large differences in rate of survival except as noted above, and no indication of any marked "resistance" to survival. The relation between oviposition and survival has been shown in figure 1. The only important deviation from the expected is in the case of the second and third plantings of Brookhaven sweet corn, which had a higher survival than the rest of the group.

Stage of growth and survival.—As stated above, all plants were in stages of growth favorable to survival during the entire season of infestation. No major effects of stage of growth would be expected and obviously none occurred.

Sugar content and survival.—The percent of sugar in the plant sap has been listed in Table 4. The general trend was increasing sugar content as the plants grew. There was also a trend of decreasing sugar in the sap as the ears formed. Contrary to expectation, the sweet corn Brookhaven contained no more sugar than Oh51A×Oh43.

The relation between sugar content and survival is shown in figure 2. With the best fit possible in the curve, there is no clear-cut correlation shown. Certainly survival did not increase as more sugar was present. It must be pointed out that the sugar content of the sap was above 5 per cent with two minor exceptions. Beck (1950) found that 5 per cent glucose was sufficient for normal growth.

SUMMARY.—The relation between sugar content of corn plants and survival of larvae of the European corn borer was studied (1) in two varieties of early sweet corn, and (2) in an inbred and two single cross hybrid field corns and a late sweet corn.

The early sweet corn was infested more in relation to growth stage than to sugar content. The variety Washington, which had the higher sugar content, had no greater survival of larvae.

The field corns and the late sweet corn were in stages of growth favorable to survival of corn borers. There was no relation between sugar content and infestation, nor between sugar content and survival. The single cross Oh51A×Oh43, resistant to the corn borer in the Middle West, had a rate of survival almost as high as the sweet corn Brookhaven. Sugar content was substantially greater than 5 per cent, the amount used by Beck (1950) as adequate in nutrition studies.

LITERATURE CITED

Batchelder, C. H. 1949. European corn borer location on the corn plant as related to insecticidal control. U.S.D.A. Tech. Bul. **976.**

Beard, R. L. 1943. The significance of growth stages of sweet corn as related to infestation by the European corn borer. Conn. Agr. Expt. Sta. Bul. **471.**

Beard, R. L., and Turner, N. 1942. Investigations on the control of the European corn borer. Conn. Agr. Expt. Sta. Bul. **462.**

Beck, S. D. 1950. Nutrition of the European corn borer, *Pyrausta nubilalis* (Hbn). II. Some factors of diet on larval growth characteristics. Physiol. Zool. **23:** 353–61.

Beck, S. D., and J. H. Lilly. 1949. Report on European corn borer resistance investigation. Iowa St. Col. Jour. Sci. **23:** 249–59.

Turner, N., and R. L. Beard. 1950. Effect of stage of growth of field corn inbreds on oviposition and survival of the European corn borer. JOUR. ECON. ENT. **43:** 17–22.

DR. SWEETLAND TO VISIT EUROPE

Dr. Harvey L. Sweetman, of the University of Massachusetts, writes that he plans to spend most of the Summer in Europe, winding up his stay by attending the Ninth International Congress of Entomology in Holland.

Biological Assay of Residues of DDT and Chlordane in Soil Using *Macrocentrus ancylivorus* as a Test Insect

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The use of DDT or chlordane for the treatment of soil in nursery plots is authorized by the Bureau of Entomology and Plant Quarantine (1947 and 1949 amendments) as a basis for the certification of plants with soil for shipment from areas under quarantine because of the Japanese beetle, *Popillia japonica* Newm. When either of these materials is used to meet certification requirements, a specified amount must be applied in a prescribed manner. Continuance of certified status beyond the first season requires supplemental applications, the quantities needed to bring the soil content up to the required concentrations being determined by annual soil analyses.

The chemical method developed by Koblitsky & Chisholm (1949) for determining amounts of DDT in soil, which may also be used for determining chlordane, involves the determination of total organic chlorides. When both DDT and chlordane are present, as is often the case, the total chlorides gives no information on the amount of each material in the soil, which would indicate how much to add to bring the treatment up to quarantine standards. It is conceivable also that there might be a gradual accumulation of relatively nontoxic chlorine-bearing decomposition products of DDT or chlordane in the soil. If so, the determination of total chlorides would not provide a true index of the toxicity of the residue.

Studies of methods of biological assay of DDT and chlordane were undertaken in February 1950, with the hope that they would provide a solution for these problems in a practical method for evaluating residues of these materials in the soil. Although the studies have been in progress for a short time only, the results may be of interest to those concerned with insecticide residues in soil.

Preliminary tests with third-instar Japanese beetle grubs, house flies, *Musca domestica* L., the oriental fruit moth parasite *Macrocentrus ancylivorus* Roh., and other insects showed *Macrocentrus* to be the most practical insect for use in the biological assay of soils. It is very sensitive to small amounts of chlorinated hydrocarbons in soil. Small variations in the amount of toxicant in the soil cause very significant differences in the insect's responses. The reactions of the insect progress so rapidly that they are completed within a few hours. *Macrocentrus* can be produced in the quantities required throughout the year.

REACTIONS OF *Macrocentrus* TO DDT AND CHLORDANE.—When *Macrocentrus* adults are introduced into a petri dish containing soil or wet filter paper, they walk in a random manner over the bottom, sides, and top. If no DDT or chlordane is present, the insects soon congregate on the underside of the top of the dish, where they rest quietly, with only occasional movements about the container thereafter.

When a minute quantity of chlordane is present, the insects continue their random walking for a longer period, at an accelerated tempo, and then gather at the top of the dish, where they sit motionless except for a continuous movement of the antennae. After a short time they lose their ability to cling to the glass, and drop to the bottom. They may return to the top and then fall off again, sometimes two or three times, but they soon become unable to climb, and remain standing on the bottom of the dish with the anterior portions of their bodies extended upward at an angle of about 45 degrees. Paralysis of the legs, beginning with the anterior pair, progresses rapidly. The parasites then begin to move rapidly about the bottom of the dish, propelled by the violent beating of their wings. Gradually all movement ceases. The criterion of definite reaction adopted for bioassay purposes is

[1] This investigation was conducted at the Japanese Beetle Laboratory of the Division of Fruit Insect Investigations, Moorestown, N. J. Adults of *Macrocentrus ancylivorus* Roh. were reared at the Oriental Fruit Moth Laboratory of that Division with the cooperation of H. W. Allen and E. L. Plasket of that laboratory. R. D. Chisholm and L. Koblitsky, of the Division of Insecticide Investigations, prepared standard solutions, made extracts of soils, conducted chemical determinations of the total organic chloride in soils, and offered valuable suggestions during the course of the work. The soils from quarantined commercial nurseries were taken by the Division of Japanese Beetle Control during the annual sampling of the treated plots.

the stage when the insects remain standing on the bottom of the dish with their bodies at an angle of about 45 degrees. Any of the subsequent symptoms or death could be used for the same purpose.

When DDT is present, *Macrocentrus* adults continue their random walking for several hours with only occasional short periods of rest. The tempo becomes progressively more rapid until the movement is an erratic hopping, usually with the wings partially extended and the tip of the abdomen bent downward. Paralysis of the legs develops gradually. The power of locomotion is ultimately lost and the legs are extended backward, parallel with the longitudinal axis of the body. The criterion of definite reaction used in the bioassay of DDT was death.

A study was made of the reaction of *Macrocentrus* males and females to chlordane. The males reacted significantly faster when no females were present. Males in the presence of females, females in the presence of males, or a mixed group as a whole reacted at about the same rate as females alone. These tests indicated that mixed groups could be used for making biological assays but somewhat more consistent results were obtained when only one sex was used.

In another experiment the effect of age and food on the reaction to the two toxicants was determined. Adults up to 2 days old were placed in dishes with and without honey as food. It was found that the age of the insects within these limitations was not a factor. With tests completed within 30 hours it was not necessary to introduce food, provided the insects had been fed previously.

DEVELOPMENT OF METHODS.—The first biological assays in which *Macrocentrus* was employed as the test insect were made with the soil itself in petri dishes. These tests showed that residues from soil applications of DDT or chlordane could be determined with a standard deviation of about 1 pound per acre. Further investigations indicated, however, that the rate of reaction of the insects may be modified to such an extent by variations in texture and organic content of soils, and by the degree of weathering of the toxicant, that a direct assay of soil as it comes from the field is not practical.

Attention was next turned to methods of extracting the insecticide from soil with a suitable solvent and making a biological assay of the toxicant in the extract, in the hope that interfering factors encountered in the work with soils could be eliminated. These studies resulted in a tentative method of conducting biological assays of DDT and chlordane in the soil, which is outlined below:

Each sample of soil is a composite of 50 borings, each 2 inches in diameter and 3 inches in depth, taken systematically over an area up to 20,000 square feet. The composite sample is brushed through a 4-mesh screen, thoroughly mixed, weighed, and then put into a can of such dimensions that the soil is at least 8 inches deep. A subsample of the soil in the can consisting of seven borings is then taken with a steel tube 1 inch in diameter. This subsample is weighed, exposed in shallow pans until nearly air-dry, and then weighed again.

Three hundred grams of nearly air-dry subsample and 300 milliliters of benzene-isopropanol solvent (2:1 by volume) are placed in a 1-quart mason jar. The jar is sealed with a glass or plastic-lined lid and placed for 30 minutes on a shaking machine, which rotates the jars end over end about 25 times per minute. The extract is filtered by gentle suction through a Büchner funnel into a flask.

Standards of insecticidal action are prepared by dissolving known amounts of the toxicants in benzene-isopropanol solvent. The DDT standards contain 7, 14 and 28 micrograms per milliliter, and the chlordane standards 1.75, 3.5, 7 and 14 micrograms per milliliter. The standard solutions are prepared each week and kept in dark glass-stoppered bottles in the dark.

A 10-milliliter aliquot of each soil extract and 10-milliliter portions of the standard solutions are placed in separate test tubes, and then a half-teaspoonful of activated charcoal is added to each. The tubes are closed with stoppers, and then shaken 30 times per minute for 30 minutes. The solutions and extracts are then filtered through filter paper.

In a typical biological-assay series 40 petri dishes which contain 3 standards and 17 test samples in duplicate are used. A filter paper 9 cm. in diameter is placed in each dish, and then 1 milliliter of each standard solution or extract is put on each of two filter papers in separate dishes. The

solvent evaporates completely in 30 minutes. After 45 minutes 1 milliliter of water is also added to each filter paper, and 20 *Macrocentrus* adults, previously anesthetized with carbon dioxide to facilitate handling, are introduced into each dish. The dishes are closed immediately, sealed with masking tape, and then placed in a lighted chamber at a temperature of 80° F. The reaction of the insects is more rapid and consistent when water is added. Sealing the dishes with masking tape prevents loss of moisture and toxicant in the vapor phase.

The assay for chlordane is usually completed within 3 hours after introduction of the test insects. At intervals of 15 minutes after the insects are introduced, a record is made of the number affected in each dish. From these data the time for each treatment to affect 50 per cent of the insects is determined. By comparing this value for a sample with similar values for the standards and interpolating, the micrograms of chlordane in 1 milliliter of the extract, which is equivalent to 1 gram of soil, may be determined.

The assay for DDT is slower, requiring 18 to 24 hours after introduction of the test insects, and is not so precise as the assay for chlordane. The parasites are affected by DDT only as the result of a chance encounter with particles of the toxicant while walking on the treated filter paper. The time that they are off the filter paper is an indefinite and variable factor. With chlordane they are affected by the gas evolved and by the particles on the filter paper, so that they are exposed continuously to the action of the toxicant. Tests are under way to improve the assay for DDT. In this paper the amount of DDT was estimated by comparing the mortality in a test sample with the concentration-mortality curve of the standards at a time when the mortality is approximately 20 per cent with the 7-microgram and 80 per cent with the 28-microgram standard.

When both chlordane and DDT are present, the chlordane is determined in the same way that it is when no DDT is present. Repeated tests have shown that DDT in amounts usually present in the soil does not interfere with the assay for chlordane. When the assay for chlordane is completed, the filter paper is successively dried and wetted with water, usually 10 or 12 times, until there is no reaction of *Macrocentrus* to the chlordane standards within 20 hours. This procedure facilitates the evaporation of chlordane from the filter paper. Then DDT, which is not affected by this procedure, is assayed.

Consideration was given to the best way to apply the extracts in petri dishes. When solutions of chlordane or DDT were applied directly to the surface of the glass and allowed to evaporate, the effect of the residual deposits on *Macrocentrus* was variable and it was difficult to differentiate between concentrations. Deposits on filter paper gave much better results.

It was estimated that 14 micrograms of a toxicant on a filter paper 9 cm. in diameter would be equivalent to 10 pounds of the material in the upper 3 inches of an acre of soil. In converting micrograms of a toxicant per gram of a nearly air-dry sample of soil into pounds per 3-inch acre *in situ*, consideration must be given to the weight and the volume of the original sample and to the loss of moisture while the soil is being prepared for assay. The following formula may be used:

$$\text{Pounds per 3-inch acre} = (U \times W_1 \times W_3 \times 41{,}486) / (S \times W_2 \times 471.24)$$

where

U = weight of toxicant in the aliquant tested (grams).
S = weight of nearly air-dry subsample of soil represented by the aliquant tested (usually 1 gram).
W_1 = weight of nearly air-dry subsample (grams).
W_2 = weight of subsample taken from screened composite before drying (grams).
W_3 = weight of screened composite sample of soil (grams).
471.24 = volume of composite sample of soil taken in 50 borings (cubic inches).
41,486 = factor to convert grams per cubic inch to pounds per 3-inch acre.

Extracts of Wauseon sandy loam, Paxton loam, and Lorrain clay loam containing 7 micrograms of chlordane per milliliter were assayed biologically to determine the reliability of the method. Only three-fourths of the chlordane present in Wauseon sandy loam and Paxton loam and only one-third of the amount in Lorrain clay loam were indicated by the assays. When the amount of extract on the filter paper was increased, the pro-

Table 1.—**Chlordane content of upper 3-inch layer of soil in cultivated plots at Moorestown, N. J., 18 months after treatment, determined by chemical analyses and assays with *Popillia* and *Macrocentrus*.**

Chlordane Applied per Acre	Crop Rotation	Chlordane Determined per Acre		
		Chemical Analysis	Biological Assay with—	
			Popillia	*Macrocentrus*
Pounds		*Pounds*	*Pounds*	*Pounds*
10	Rye and soybeans	3.59	3.17	4.05
	Soybeans and corn	3.29	2.50	3.58
	Corn and rye	3.22	3.47	4.18
20	Rye and soybeans	4.40	3.37	4.50
	Soybeans and corn	4.98	3.40	3.80
	Corn and rye	2.95	3.23	3.25

portion of chlordane that could be recovered was further reduced.

The extraction of soil with benzene-isopropanol removed not only the toxicant but also any oils, fats, waxes, and resins present. These substances in the extracts not only made it difficult to wet the filter paper with water, but apparently coated the toxicant to the extent that only part of it affected the insects. It became evident that these inhibiting substances would have to be removed before a proper evaluation could be made of the toxicant.

The addition of hygroscopic compounds or wetting agents to the water improved the wetting of the paper, but did not overcome the inhibiting action of the soil constituents. The use of other solvents, including methanol, ethanol, isopropanol, acetone, and petroleum ether, did not improve the situation. The inhibiting constituents could not be removed by subjecting the extracts to a temperature of −17° C., or by washing with dilute sulfuric acid or with aqueous solutions of sodium carbonate. When activated charcoal was added to the extracts, it removed the color and practically all of the inhibiting constituents. The charcoal also removed two-thirds of the chlordane and half of the DDT, regardless of the concentration of the toxicants. When both the standard solutions and the extracts were treated with activated charcoal in the same manner, 94 per cent of the chlordane present in Wauseon sandy loam and Paxton loam and 98 per cent of that in Lorrain clay loam could be detected with the biological assay method. A reasonably accurate assay of the DDT in soil could also be made when the extracts were treated with activated charcoal.

ASSAY OF CHLORDANE IN FIELD SOILS.—Samples of soil were taken from cultivated plots at Moorestown, N. J., that had been treated about 18 months previously with chlordane at the rate of 10 or 20 pounds per acre. Part of each sample was used to make a slow, laborious assay with third-instar *Popillia* larvae. Standards were prepared by mixing chlordane with soil at rates varying from the equivalent of 0.25 to 2 pounds per acre. Test samples were diluted 1:4 with untreated soil. For the assay 1.5 cubic feet of each standard and test sample were required. The soil was placed in trays at a temperature of 80° F., and 250 third-instar larvae were introduced into each treatment, 50 in each tray. At weekly intervals the number surviving each treatment was determined. By comparison of the survivals in a test sample with the survivals in known amounts of chlordane and interpolating, an estimate was made of the amount of chlordane in the test

Table 2.—**Determination of chlordane and DDT in the same soil by biological assay with *Macrocentrus*, and a comparison of the total organic chloride determined biologically and chemically.**

Number of Samples	Average Amount of Insecticide per Acre Determined by Biological Assay		Average Amount of Organic Chloride per Acre as Determined		
	Chlordane	DDT	Biologically	Chemically	Difference
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*
10	1.63	5.11	3.60	3.40	+0.20
11	2.47	4.68	3.92	4.49	− .57
2	2.09	6.77	4.71	5.66	− .95
12	2.78	10.42	6.99	6.50	+ .49
9	3.63	12.00	8.33	7.50	+ .83
6	2.54	15.96	9.61	10.38	− .77

sample. The remainder of each sample was extracted with the benzene-isopropanol solvent. The extract was used for determination of total organic chloride by the chemical method and for an assay with *Macrocentrus*.

In all, 42 chemical analyses, 18 assays with *Popillia*, and 32 assays with *Macrocentrus* were made. The chlordane was estimated from the total organic chloride by multiplying by the factor 1.56. The average amounts of chlordane determined by these methods are summarized in table 1.

After 18 months the amount of residual chlordane was about the same in all plots, regardless of the amount applied and the crops grown. An analysis of variance demonstrated that there was no significant difference in the results obtained by chemical analysis or by biological assay with *Popillia* or *Macrocentrus*. This is very important. It demonstrates that the chlordane residue in this soil did not decompose to any great extent into nontoxic chlorine-bearing compounds. Furthermore, it shows that the relatively rapid assay which can be made with *Macrocentrus* is a good index of the reaction of *Popillia* larvae. The data indicate that either chemical analysis or biological assay with *Macrocentrus* may be used to determine the amount of toxicant in the soil when only chlordane is present.

ASSAY OF DDT AND CHLORDANE IN THE SAME SOIL.—Fifty samples of soil were taken from plots in commercial nurseries containing both DDT and chlordane. Extracts of these samples were analyzed chemically to determine the total organic chloride, and assays were made with *Macrocentrus* to determine the DDT and chlordane present. The organic-chloride equivalents of the DDT and the chlordane determined biologically were estimated by dividing the amount of chlordane by 1.56 and the amount of DDT by 2.0 and adding the quotients. The samples were arranged in groups according to the total organic chloride as determined by chemical analysis, and the average of each group was determined. The data from these assays are presented in table 2.

The difference in the total organic chloride as determined biologically and chemically was less than 1 pound per acre. This close agreement indicates that the biological assay had separated the DDT and chlordane in about the same proportions as they occurred in the soil. In view of the slow, approximate assay for DDT, possibly the most practical procedure would be to determine the total organic chloride chemically and the chlordane biologically and to calculate the DDT from the organic chloride in excess of that in the chlordane.

PRELIMINARY TESTS WITH OTHER CHLORINATED HYDROCARBONS.—The reactions of *Macrocentrus* to residues of aldrin and dieldrin were similar to those with chlordane, except that the insects passed through the different stages more rapidly. Preliminary tests with soil from field plots showed that these materials may be determined by biological assay with the same method as that used for chlordane. It is hoped in the near future to investigate the possibility of assaying these and other chlorinated hydrocarbons in the soil.

SUMMARY AND CONCLUSIONS.—A tentative biological assay of soil residues of chlordane and DDT, alone and in combination, has been developed, with *Macrocentrus ancylivorus* Roh. as a test insect. Extracts of the soils made with a mixture of benzene and isopropanol are clarified with activated charcoal. When only one toxicant is present, the extracts are placed on filter paper in petri dishes, and the reaction of the insects to the residue of each test sample is compared with the reactions to known residues of the toxicant. From this comparison the amount of the toxicant is estimated and expressed as pounds per 3-inch acre.

When both materials are present, the chlordane is assayed and then removed by wetting and drying the filter papers before assaying the DDT residues. Possibly the most practical procedure would be to determine the total organic chloride chemically and the chlordane biologically and to calculate the DDT from the organic chloride in excess of that in the chlordane.

The biological assays indicate that the chemical determination of total organic chloride in the soil is a good basis for estimating insecticidally effective amounts of either chlordane or DDT.

Preliminary tests showed that other chlorinated hydrocarbons in soil may be determined biologically.

LITERATURE CITED

Bureau of Entomology and Plant Quarantine. 1947. Treating procedures authorized for use as a basis for certification of products regulated by the Japanese beetle. Unnumbered publication, June 2, 1947, with amendments of Jan. 6, 1949.

Koblitsky, L., and R. D. Chisholm. 1949. Determination of DDT in soils. Jour. Assoc. Off. Agr. Chemists 32: 781–6.

Response of the German Cockroach to Sublethal Concentrations of DDT and Benzene Hexachloride[1]

JAMES MCD. GRAYSON,[2] *Virginia Agricultural Experiment Station, Blacksburg*

Of considerable interest in recent years has been the appearance of strains of insects which are resistant to certain of the newer insecticides. In some cases this resistance is of such a degree, and has been developed within such a short time, that a serious problem is presented. Since early 1947 well over 100 scientific articles dealing with resistance of insects or other arthropods to some of the newer insecticides have been published. The literature up to 1949 relative to development of resistance to chemical insecticides has been thoroughly reviewed by Babers (1949). In an earlier work, Smith (1941) discussed the subject of racial segregation in insect populations from a broad standpoint. Apparently there is no published information on populations or strains of the German cockroach which have shown abnormal resistance to insecticides.

The work reported here was begun in the fall of 1947. Strains of the German cockroach have since been reared in the laboratory through seven generations of selection for survival to treatments with DDT and benzene hexachloride. This paper is a progress report on the results obtained from studies on development of insecticidal resistance and reproductive response in the different strains.

GENERAL PROCEDURE.—Stock cultures of the different strains of German cockroaches were maintained in aquaria of 6-gallon capacity containing tiers of pressboard. Food consisted of dried dog food with an occasional supplement of plant food. Food and water were provided at all times. In every generation a population of 2000 to 3000 roaches was reared for each strain. The cultures were maintained in a laboratory at a temperature of 22° to 26°C.

The criterion of selection, after the first generation, was 75 per cent mortality. Thus, only those adults surviving treatments in each generation which gave 75 per cent mortality, or higher, were allowed to rear progeny for the next generation.

MATERIALS.—For selection of the treated strains during the first several generations, a 50 per cent wettable form of DDT and a wettable form of benzene hexachloride containing 5 per cent of gamma isomer were used. Homogeneity of the suspensions was facilitated by addition of a small amount of spreader-sticker and treatment in a Waring blendor. Subsequent selections were made by treatments with purified, high-melting (108° C. m.p.) DDT, and the pure gamma isomer of benzene hexachloride. Each material was dissolved in acetone prior to preparation of the acetone-water suspensions and, in the case of higher DDT concentrations, a spreader-sticker at the rate of 1 to 3200 was added.

RESISTANT STRAINS.—Roaches within known age limits were obtained by removing all adults from the stock cultures at 5- to 7-day intervals. For treatment they were placed in small screen cages, approximately 30 per cage, and dipped for a period of 10 seconds in the insecticidal suspensions at 30° C. Mortality counts were made at the end of 3 and 6 days following treatment. Roaches which were unable to exhibit active locomotion were considered as dead.

The mortality data obtained from exposure of treated and untreated strains of German cockroaches to different concentrations of DDT are shown in figure 1.

[1] A report of progress.

[2] Acknowledgment is made to M. E. Terry, Statistical Laboratory, Virginia Polytechnic Institute, for assistance in some of the statistical analyses.

Table 1.—Percentage mortality at the end of 6 days in treated[1] and untreated strains of the German cockroach following treatment with benzene hexachloride.

Concentration[2]	Males		Females	
	Untreated Strain	BHC Strain	Untreated Strain	BHC Strain
.010	11.4	24.3	—	—
.015	64.3	36.2	—	—
.020	84.8	71.6	16.0	6.0
.025	100.0	92.8	43.1	—
.030	100.0	93.5	73.9	55.4
.035	—	—	91.9	68.8
.040	—	—	—	84.0
.050	—	—	92.9	77.5
.060	—	—	—	100.0
.075	—	—	100.0	100.0

[1] Selected through seven consecutive generations from tests giving 75 per cent or higher mortality in most cases.
[2] Gram of pure gamma isomer of benzene hexachloride per liter of acetone-water suspension.

The regression lines were fitted to the points by the method of least squares (Bliss, 1935). The calculated concentrations of DDT, expressed as grams per liter of insecticidal suspension, required for 50 and 95 per cent kill, respectively, were: DDT-strain males, 0.337 and 2.10; untreated-strain males, 0.146 and 0.523; DDT-strain females, 2.49 and 12.28; and untreated-strain females, 0.174 and 1.57.

The toxicity of benzene hexachloride to treated and untreated strains of the German cockroach is shown in table 1. From 53 to 218 adult roaches were used in most cases for determining the mortality at each concentration. When these data were plotted on logarithmic probability paper, and the regression lines fitted by eye, the approximate amounts per liter of insecticidal suspension required to give 50 per cent kill were: benzene hexachloride-strain males, 0.0163 gram; untreated-strain males, 0.0140 gram; benzene hexachloride-strain females, 0.0305 gram; and untreated-strain females, 0.0260 gram.

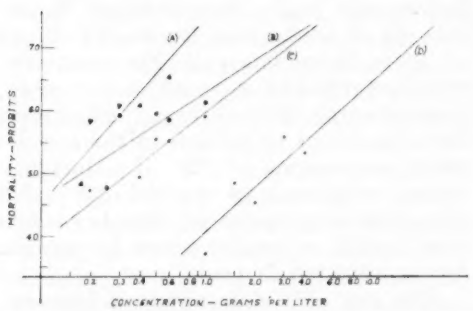

FIG. 1.—Mortality of treated and untreated strains of the German cockroach at the end of 6 days following treatment with DDT. (A) Untreated-strain males; (B) untreated-strain females; (C) DDT-strain males; (D) DDT-strain females. From 48 to 212 adult roaches were used in most cases for determining the location of each point.

Table 2.—Reproductive performance[1] of female German cockroaches from treated and untreated strains.

Generation	Strain	Nymphs Produced (Avg.)	
		Per Female	Per Egg Case
F^4 through F^7	DDT	77.9	29.0
	BHC	86.6	30.5
	Untreated	84.9	31.1
F^7	DDT	69.4	27.5
	BHC	91.5	30.9
	Untreated	117.8	37.5

[1] For each generation a record was kept of the production of approximately 30 females for a period of 114 days.

REPRODUCTIVE RESPONSE.—For determination of reproductive response, data were obtained each generation on the performance of approximately 30 female roaches in each strain for a period of 114 days. These were reared by placing 15 females, with an adequate number of males, in each of two battery jars. At appropriate intervals the nymphs and empty egg cases were removed.

The results are briefly summarized in table 2. The accumulated data obtained in the fourth through the seventh generations were analyzed by the analysis of covariance to eliminate the effect of female deaths during the observation

Table 3.—Average[1] length and width of empty egg cases produced by treated and untreated strains of the German cockroach.

Generation	Strain	Width (mm.)	Length (mm.)
F^4 through F^7	DDT	3.73	7.90
	BHC	3.84	8.01
	Untreated	3.83	8.07
F^7	DDT	3.61[2]	7.42[2]
	BHC	3.82	7.71[2]
	Untreated	3.85	7.98

[1] Measurements were made of 100 to 300 empty egg cases each generation for the different strains.
[2] Significantly lower ($P<.01$) than untreated strain.

period. No significant difference was found in the performance of the different strains. However, there was a rather consistent tendency in all of the generations for less nymphs per female and nymphs per egg case to be produced in the DDT strain than in the other two. After additional data in future generations have been obtained, perhaps significant differences between strains can be shown by analysis.

EGG CASE MEASUREMENTS.—In all generations measurements were made of the length and width of from 100 to 300 empty egg cases for each strain.

The results are shown in table 3. An analysis of the data obtained in the seventh generation revealed that the variances in the different strains were not homogeneous. Using Fisher-Behrens' approximation test (Fisher 1941), however, it was found that both the length and the width of empty cases in the DDT strain and the length of them in the benzene hexachloride strain, were significantly less than those occurring in the untreated strain. The accumulated data obtained in the fourth through the seventh generations indicate little difference in size of empty egg cases between the BHC strain and the untreated strain, but considerable difference between the DDT strain and the untreated strain.

SUMMARY.—Strains of the German cockroach have been reared in the laboratory through seven generations of selection for survival to treatments with DDT and benzene hexachloride. The criterion of selection after the first generation was survival to treatments which gave 75 per cent or higher kill. The procedure employed in making the treatments is described.

In the seventh generation, 2.3 and 4.0 times as much DDT were required to kill 50 and 95 per cent, respectively, of the DDT-strain males as untreated-strain males. Similarly, 14.3 and 7.8 times as much DDT were required to obtain 50 and 95 per cent mortalities of the DDT-strain females as untreated-strain females. The male and female roaches in the benzene hexachloride strain were only slightly more resistant in the seventh generation to benzene hexachloride than those of the untreated strain.

No significant difference in reproductive performance between treated and untreated strains was found. However, the average number of nymphs per female and nymphs per egg case produced within the DDT strain were rather consistently lower than in the other two strains. It is expected that significance will be demonstrable after more data have been obtained and the precision of the analysis thereby improved.

The width and length of empty egg cases produced in the seventh generation by DDT-strain females, and the length of those produced by benzene hexachloride-strain females, were significantly less than similar measurements made on egg cases produced by females within the untreated strain.

LITERATURE CITED

Babers, F. H. 1949. Development of insect resistance to insecticides. U.S.D.A., Bur. Ent. & Pl. Quar., E-776.

Bliss, C. I. 1935. The calculation of the dosage-mortality curve. Ann. Appl. Biol. **22**(1): 134–67.

Fisher, R. A. 1941. The asymptotic approach to Behrens' integral with further tables for the d-test of significance. Ann. Eug. London **11**: 141–72.

Smith, H. S. 1941. Racial segregation in insect populations and its significance in applied entomology. JOUR. ECON. ENT. **34**(1): 1–13.

AN UNUSUAL FOOD HABIT OF *Monochamus titillator* FAB.

On investigating an urgent request from a fashionable dress shop in Catonsville, Maryland, to "do something about some big bugs that are eating our dresses in the show window," two specimens of *Monochamus titillator* Fab. were secured. The beetles had been feeding on a rayon dress and had chewed a number of large holes through the material. The proprietor of the store stated that a few pieces of new lumber had been used in making the show window, but it was not possible to ascertain if the beetles had emerged from the wood. The beetles had ruined two expensive dresses, however the owner said that the number of people who came in to inform them that insects were eating dresses in the show window, almost made up for the loss!

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Studies of Arsenical Residues on Cauliflower

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Cauliflower is grown commercially in various parts of the United States, including several areas in the southern states. In the South the crop is grown during the latter part of the summer, in the fall, and early in the winter, when insects in general are most abundant and destructive. Cauliflower is attacked by the same species of caterpillars that infest cabbage and other related crops. Nearly every year in the South, advanced stages of the crop are infested with damaging numbers of one or more of these species and control measures are required.

The results of a previous study (Smith *et al.* 1937) showed that it is unsafe to apply arsenicals on cabbage after the plants start heading, that is, after plant parts that will be included in the market product are formed and exposed. Reid *et al.* (1941) found that several species of caterpillars, especially the Agrotinae, were not controlled effectively by any of the so-called nonpoisonous insecticides, but required one that leaves a residue detrimental to the health of human beings. A study was initiated, therefore, in 1939, and continued throughout 1942 to determine the stage of development of cauliflower plants when it is safe to apply arsenical insecticides. For the purpose of this study residues of less than 0.01 grains of arsenic per pound of cauliflower were arbitrarily considered to be safe.

CROPPING PRACTICES.—In Louisiana the major part of the cauliflower crop is started by planting the seed in the field rows, usually in hills about 24 inches apart late in July or early in August. A few growers, however, sow the seed in plant beds and later transplant the seedlings to the field. The crop starts to mature about November 25; however, the date varies from early in November to late in December. The harvest period usually covers 4 to 6 weeks.

DESCRIPTION OF EXPERIMENTS.—The experiments were conducted on cauliflower of the Early Snowball variety. The crops were planted and cultivated according to the practices employed by local commercial growers. Mixtures of calcium arsenate and paris green were used. The applications were begun when the plants were small and were made at 10- or 11-day intervals. The applications were made with rotary-type hand dusters, except the last two in 1939, which were made with a two-row wheelbarrow type power duster. One trip was made along each row at each application until the plants were about 15 inches high, and two thereafter, one on each side.

The analyses of the calcium arsenate and paris green used in these experiments are given in table 1.[3]

Ten heads per plot were taken for arsenic-residue determination. They were quartered and two opposite quarters of each head were passed through a food chopper. The chopped material was thoroughly mixed and duplicate subsamples (200 gm. each) were weighed and turned over to the chemists[4] for analysis.

Table 1.—Analyses of arsenical materials used in experimental dusting of cauliflower at Baton Rouge, 1939–42.

CONSTITUENTS	CALCIUM ARSENATE	PARIS GREEN
	per cent	*per cent*
Moisture	0.92	0.52
Arsenious oxide		
Total	.03	55.38
Water-soluble	—	1.34
Arsenic oxide		
Total	41.12	.54
Water-soluble	.15	—
Calcium oxide	45.59	—
Copper oxide	—	32.01

The field plan of the 1939 experiment consisted of three plots from 0.25 to 0.5 acre in area, each located in a different field, whereas each of the other experiments consisted of four plots 105 feet long and 5 rows wide.

In 1939 the insecticide applications were discontinued on all the plots at the same time, approximately when

[1] Resigned August 8, 1944.

[2] In cooperation with the Louisiana Agricultural Experiment Station, Baton Rouge, Louisiana.

[3] These analyses were made by the Division of Insecticide Investigations of the Bureau of Entomology and Plant Quarantine.

[4] J. L. Farr, of the Louisiana Agricultural Experiment Station, analyzed the samples for the 1939 experiment and W. P. Denson, of the same station, analyzed the samples for the experiments in 1940–42.

the edible portion, or curds, became visible on the most advanced plants. In subsequent years the last applications were made, as nearly as could be predicted, 30, 20, 10, and 0 days before the curd became visible on the four plots, respectively. Harvest was expected about 3 weeks after the curds became visible. The rate of curd development varied so much, however, that the first cutting of harvest in 1940 and 1942 came before the curds were expected to become visible, so that only three of the four treatment schedules materialized. In 1941 harvest was later than expected.

The dust mixture used in 1939 contained 19 parts of calcium arsenate and 1 part of paris green by weight. In subsequent years only 10 parts of calcium arsenate were used to each part of paris green to agree more closely with commercial practice.

Residue determinations in 1939 were made from a single 10-plant sample from each plot each week throughout the harvesting period, or until the residue remaining on the plants became insignificant. In the 1940–42 experiments, however, a sample of the earliest maturing plants was taken only once from each plot, except in 1940, when second samples were taken from two of the plots, to determine the effects of 21 days of plant growth and weathering in reducing the relatively heavy deposits of arsenic found on the first samples.

On 1939 the plants comprising the samples were trimmed as is done for the retail trade, by removing all but two or three circles of the leaves and cutting back the remaining leaves about even with the tip of the curd. In the other three years (1940 to 42) the plants retained practically all the good foliage untrimmed. (In Louisiana most of the cauliflower is marketed either untrimmed and loose or in six-plant bundles, tied so that half the plants butt in opposite directions.)

The characteristic of cauliflower to grow from within as the leaves loosen is an important factor in determining when applications of poisonous insecticides should be discontinued in order that the harvested product may not contain an excess of harmful residue. Hence, beginning with the 1940 experiment, a new phase pertaining to plant growth was added to the experiment, namely ascertaining the approximate time before harvest during which foliage is produced and consequently will be exposed to insecticide applications that leave a residue on the marketable product. The phase of the experiment consisted of slitting the midrib of the youngest exposed leaf on each of 100 plants per plot at the time of the last arsenical application. By the position of this leaf at harvesttime a

Table 2.—Arsenical residue on the marketed portion of 10-plant samples of cauliflower dusted with a mixture of 1 part of paris green and 10 parts of calcium arsenate.

Year and Plot Number and Date of First Application	No. Applications	Pounds per Acre Application	Date Last Dusting	Days Last Dusting to Sampling	Inches Rainfall During Period	Leaves on Marketed Product		Grams Residue per Pound Marketable Product
						Not dusted	Dusted	
Aug. 12, 1940								
1	7	9	Oct. 14	29	7.12	30	0	.0037
2	8	11	Oct. 24	19	7.12	12	18	.0536
				40	9.55	34	0	.0008
3	9	12	Nov. 4	8	5.89	5	25	.1335
				29	8.32	18	13	.0012
4	0	—	—	—	—	—	—	.0009
Sept. 18, 1941								
1	5	9	Oct. 30	62	6.35	25	4	.0007
2	6	12	Nov. 10	51	5.08	23	8	.0039
3	7	12	Nov. 19	42	5.08	21	11	.0035
4	8	12	Nov. 29	32	4.43	14	17	.0165
Aug. 24, 1942								
1	6	15	Oct. 15	35	3.62	22	8	.0032
2	7	15	Oct. 26	24	1.70	12	17	.0167
3	8	14	Nov. 5	14	.19	6	26	.1125

count was made of the total number of leaves, both dusted and undusted, that remained on the marketed product.

RESULTS.—In 1939 the highest residue reading was only 0.0025 grain of arsenic trioxide per pound, although in some cases the last application was made only 21 days before harvest. The experimental data pertaining to the arsenical residue hazard in the remainder of the study are given in table 2. Excess residues were found on the marketed cauliflower harvested 8 to 32 days after the last application of arsenicals. This indicated that a period longer than 32 days must be allowed between dusting and harvesting to avoid excess residues. Excess residues were also found whenever the marketed portion included seventeen or more leaves that had been exposed to the arsenical, but were not found when the number of such leaves was thirteen or less. Therefore, the maximum number of dusted leaves that can be retained without danger of excess residues is 13.

The data obtained in the plant-growth phase of the 1940–1942 experiments are given in table 3. The short harvesting period in 1941 was due largely to two factors: First, harvesting was begun a week or 10 days late; because of an approaching blizzard the experiment was closed before all the plants were fully mature. The number of leaves retained on the untrimmed heads as marketed in Louisiana ranged from 26 to 52, including the 4 to 8 small leaves next to the curd. Some of these leaves had been exposed on the plants as long as 70 days but in only one group of plants dusted more than 32 days before harvest was there more than 13 dusted leaves per plant on the marketed product. Cauliflower dusted 33

Table 3.—The number of dusted cauliflower leaves on the marketed product of plants dusted with arsenicals at different times prior to harvest.

HARVESTING DATE	PLANTS HARVESTED	DAYS FROM LAST APPLICATION TO HARVEST	LEAVES ON MARKETED PRODUCT	
			Total	Dusted
Nov. 12	21	29	30	0
1940	21	19	29	17
	14	8	28	24
18	10	35	35	0
	11	25	35	8
	8	14	36	27
20	4	27	32	5
	1	16	31	25
26	39	43	40	0
	24	33	33	1
	32	22	32	22
28	8	45	42	0
	13	35	37	1
	21	24	33	20
Dec. 3	15	50	34	0
	12	40	34	0
	10	29	31	13
6	4	43	35	0
	2	32	35	10
11	5	58	52	0
	4	48	38	0
	8	37	34	8
Dec. 31	41	62	29	4
1941	24	51	31	8
	24	42	32	11
	26	32	31	17
Jan. 5	34	67	28	1
1942	29	56	26	2
	30	47	29	6
	45	37	29	11
8	25	70	30	1
	45	59	31	6
	46	50	30	9
	29	40	31	13
Nov. 9	3	25	26	12
	7	14	29	21
13	3	29	29	12
	3	18	30	18
19	33	35	30	7
	22	24	28	16
	5	14	32	26
20	5	36	27	6
	5	25	29	16
25	14	41	30	3
	23	30	30	12
	25	20	29	19
30	14	46	32	2
	10	35	29	9
	15	25	29	16
Dec. 4	5	50	35	1
	4	39	36	10
	4	29	26	14
8	3	43	33	7
	10	33	31	14
14	4	60	34	0
	5	49	29	1
	5	39	33	13
18	1	64	37	0
	2	53	32	0
	3	43	29	5
23	5	69	36	0
	4	58	29	0
	8	48	33	6
30	12	76	34	0
	5	65	34	0
	21	55	36	6

days before being harvested on December 8, 1942, had on the marketed product an average of 14 leaves that had been exposed to the insecticide. It appears that if dusting is discontinued at least 34 days before plants are harvested there will not be excess residue on the marketed heads.

DISCUSSION.—Rain washes much of the poison off the plants, and some is evidently removed by other weathering agents. The data show, however, that rainfall, even when amounting to more than 7 inches during the period between the last application and harvest, did not remove enough of the arsenical deposits to eliminate the hazard. The insignificance of both rainfall and the time element in removing arsenical-dust deposits from cauliflower is demonstrated by the data for plot 4 in 1941 and plot 2 in 1942 (Table 2). Plants receiving these two treatments had the same number of leaves present at the time of the last application, and practically the same amounts of residue (0.0165 and 0.0167 grain) whereas the rainfall was 4.43 and 1.70 inches and the periods between the last applications and harvesting were 32 and 24 days, respectively.

According to the data given in tables 2 and 3, the arsenical residue on cauliflower at harvest time depends largely on the stage of plant development at which insecticide applications are discontinued. These data show that untrimmed cauliflower as marketed under Louisiana conditions and having an average of more than 13 leaves per plant that were exposed to the last application, is likely to carry arsenical residues in excess of 0.01 grain per pound of plant material. The data and observations also indicate that, in order that the plants may retain less than 13 dusted leaves on the marketable product, dusting must cease about 5 weeks before harvest or about the time the curd starts forming.

This stage cannot be determined by visual inspection, because the small curds are enclosed by overlapping leaves during the first 10 or 15 days after they begin to form. Furthermore, there is no visible characteristic growth to indicate whether a field of cauliflower nearing the heading stage can safely be treated with arsenicals. The only method, therefore for ensuring that applications will not be made after the beginning of the unsafe period is one followed by R. L. Remners, a cauliflower grower of San Juan Capistrano, California. Just before an application was to be made the grower selected several of the most advanced plants and split them through the center with a sharp knife to see whether the young curds were forming. If this examination revealed curds more than 0.5 inch in diameter the plants were considered too mature for further treatment with arsenicals.

LITERATURE CITED

Reid, W. J., Jr., C. E. Smith, L. B. Reed, and W. A. Thomas. 1941. Field studies of insecticides used to control cabbage caterpillars in the South. U. S. Dept. Agr. Tech. Bul. **782.**

Smith, C. E., W. J. Reid, Jr., P. K. Harrison, and C. O. Bare. 1937. A study of arsenical dusting of cabbage in relation to poison residues. U. S. Dept. Agr. Cir. **411.**

S. F. POTTS, WINS AWARD

The Award of Merit of the Connecticut Tree Protective Association was presented to Mr. S. F. Potts of the Division of Forest Insect Investigations at its annual banquet in Bridgeport, Connecticut, January 29, 1951.

The award was given "In recognition of the outstanding contribution made to shade tree appreciation, protection, and conservation in the State of Connecticut" and was merited by Mr. Potts for his outstanding service in the development of mist blowers and concentrated sprays, a major contribution in the field of shade tree pest control.

Control of Cutworms and Aphids on Tobacco

NANCY WOODRUFF, *Connecticut Agricultural Experiment Station, New Haven*

Soil application of insecticides for control of cutworms in tobacco is a comparatively new technique. Formerly, the standard method of control was limited to the use of poison bait composed mainly of bran and paris green sprinkled around newly set plants or broadcast. This method was laborious and time-consuming since plants were baited by hand, and the treatment was effective for only a short time.

Cutworms are a perennial pest in the tobacco growing regions of Connecticut, although in recent years damage has not been severe on the whole. In the spring of 1950, tests of insecticides applied to the soil for cutworm control on broadleaf tobacco were undertaken at the Tobacco Station in Windsor.

PROCEDURE.—In one field, 10 per cent DDT dust, 10 per cent chlordane dust, and 40 per cent toxaphene emulsion, all commercial preparations, were applied to plots .2 acre in size, replicated twice, with an untreated check plot one acre in size. Dust applications were made with a small power duster at the rate of 30 lbs. per acre, whereas the emulsion was applied with a single nozzle spray gun at the rate of 1 qt. per 10 gal. of water per acre. All treatments were applied on May 31 to land previously made ready for planting. The insecticide remained undisturbed on the surface of the soil for one week prior to setting of tobacco on June 7–8.

In the same field, 50 per chlordane wettable powder was applied in the setting water at 4 oz. per 50 gal. as a test for control of wireworms. Since data were available, this treatment was also included in the cutworm tests.

Cutworm damage was estimated by counting the number of cut plants in four rows, approximately 200 ft. in length, taken at random from each plot. The first count was made on June 12, 12 days after treatment, and the second count on June 28, almost a month after treatment. On June 14, the field was re-stocked, and a record was kept of the number of plants replaced in each plot. However, the replaced plants included not only those damaged by cutworms, but those injured by other factors as well, *i.e.* disease, planting too deep, lack of moisture, etc. The data are included, as differences among plots were observed.

RESULTS.—Table 1 includes the field re-stocking as well as per cent control of cutworms based on the untreated plots. Chlordane dust and toxaphene emulsion showed excellent control twelve days after treatment. Chlordane in the setting water showed only 55 per cent control, and DDT dust was 46 per cent effective.

Since the count of plants replaced 2 days after the first setting included those seriously injured by all factors, it was difficult to evaluate cutworm treatments alone. However, both chlordane dust and toxaphene emulsion treated plots required less re-stocking than the untreated plots, whereas chlordane in setting water and DDT dust required more. A month after treatment, cutworm damage was still extensive in the untreated plots. However, this damage was confined mostly to leaf feeding rather than to whole plant destruction as at the time when young plants were set. The residual effectiveness of chlordane dust and toxaphene emulsion was reduced to 68 per cent, while chlordane in the setting water appeared to retain some residual effect, since control was not reduced. DDT, however, was only 31 per cent effective.

TOXAPHENE AS A DUST.—In another test, 10 per cent toxaphene dust was applied, at a rate of 30 lb. per acre, to a field one and one-half acres in size which had been laid out in strip plots as a comparison between ploughing and disking. This experiment was set up to measure the effects of method of preparation of soil for planting on yield and quality of tobacco. Our cutworm treatments were applied across these plots with one-half the field left as an untreated check.

One application of toxaphene dust was made on May 31 and left on the surface of the soil for ten days before setting. Four counts of damaged plants were made, and one of the number of replaced plants (Table 2). The figures represent the number of damaged plants in 20 rows, approximately 100 feet in length, on each given date. The dust gave excellent control of cutworms even

one month after treatment, whereas damage to untreated plots was quite heavy, especially after the first setting. Incidental to this experiment, it was noted that cutworm damage was always heavier on plots that had not been ploughed. This has been noted also in previous years. It is not known whether more cutworms infest land that is disked, or whether more cutworms are killed by ploughing, but at any rate, cutworm damage was less extensive on land that had been ploughed before planting.

CONTROL OF TOBACCO APHIDS.—In 1949, Turner reported that DDT dust had some repellent effect on aphids in plant bed tests. Honey-dew, which is secreted by aphids, is one of the most injurious effects of aphid infestation on cigar tobacco. Obviously it is important to keep the aphid population as low as possible by maintaining a high degree of control. A field test was devised to study the effectiveness of DDT both as a spray and as a dust when applied to plants prior to the peak of infestation. Parathion was also incorporated in this study, chiefly to obtain a quick kill of aphids present when treatments were applied, and also to examine its effectiveness as a residue. The treatments were as follows:

A. DDT 10% dust, one application.
B. DDT 10% dust, two applications, at a weekly interval.
C. DDT spray powder (25%), 2 lb. DDT/acre, one application.
D. DDT spray powder (25%), 2 lb. DDT/acre, two applications, at a weekly interval.
E. DDT 3%, Parathion 1% combination dust, one application.
F. DDT 3%, Parathion 1% combination dust, one application, followed one week later by DDT 10% dust.
G. Parathion 1% dust, one application.
H. DDT spray powder (25%), 2 lb. DDT/acre, and parathion spray powder (15%), 0.2 lb. Parathion/acre, one application.
I. DDT spray powder (25%), 2 lb. DDT/acre, and parathion spray powder (15%), 0.2 lb. Parathion/acre, one application, followed one week later by DDT spray powder (25%), 2 lb. DDT/acre.
J. Parathion spray powder (15%), 0.2 lb. parathion/acre, one application.

All treatments were applied just at the time aphids were beginning to appear on tobacco, rather than at the peak of infestation. This made possible a study of the contact action of DDT as well as its residues throughout the infestation period. It was assumed that parathion would eliminate any aphids present at the time of application in the combination treatment, and that DDT would persist and also act as a residue to prevent reinfestation of clean plants.

Table 1.—Number of plants damaged by cutworms, per cent control based on check and on number of plants replaced in field.

Treatment	Plants Damaged	Per Cent Control	Plants Replaced	Plants Damaged	Per Cent Control
	June 12		June 14	June 28	
Chlordane dust (10%)	6	91.5	54	33	68
DDT dust (10%)	38	46.4	97	70	31.4
Toxaphene emulsion (40%)	6	91.5	63	32	68.6
Chlordane (in setting water)	32	55.0	94	46	55.0
Check	71		81	102	

Table 2.—Control of cutworms with toxaphene dust (10 per cent). Number of plants damaged in 20 rows.

	Plants Damaged		Plants Replaced	Plants Damaged	
	6/12	6/14	6/14	6/19	6/28
Toxaphene	3	7	35	12	44
Check	77	61	90	132	126

Each plot measured 28 feet in length by 5 rows in width, containing approximately 100 plants, and all treatments were replicated four times. There were sixteen untreated control plots. Individual plants were dusted with small hand dusters, and sprayed with a single nozzle spray gun. The first treatments were made on July 14. Those plots requiring a second application were treated on July 21.

Two counts of aphid population were

Table 3.—Control of aphids on tobacco with formulations of DDT and parathion.

Treatment	No. of Aphids		Score[1]
	7/27	8/2	8/9
A. DDT dust, once	0	1	0
B. DDT dust, twice	4	1	0
C. DDT spray, once	276	317	1.25
D. DDT spray, twice	313	391	1.0
E. DDT & parathion dust, once	14	0	0
F. DDT & parathion dust, once & DDT dust, one week later	4	4	0
G. Parathion dust, once	1	3	0
H. DDT & parathion spray, once	0	2	.25
I. DDT & parathion spray, once & DDT spray one week later	3	4	0
J. Parathion spray, once	1	0	0
Check	381	721	2.0
Check	537	787	1.75
Check	481	451	1.75
Check	467	529	2.0

Score: 0—clean.
1—light infestation.
2—moderate infestation.
3—heavy infestation.

made, one on July 27, and another on August 2. The system employed was to count the number of living aphids on one leaf of each of five plants selected at random in each plot. Care was exercised in selecting leaves of approximately the same size near the top of the plant, since aphid infestation always begins near the top. A scoring system was used on August 8 for a final estimate of aphid infestation because the total population in the untreated control plots had decreased to such a degree. It should be mentioned that the aphid infestation on the whole in 1950 was relatively light. Rainfall for the period between the first treatment and the last observation amounted to 1.71 inches. On July 31, an inch of water was applied artificially with a sprinkler system, and again on August 9.

RESULTS.—From table 3, it can be seen that practically every treatment but two showed excellent aphid control throughout the season. The two DDT spray treatments, one and two applications, showed extremely poor control, although both treatments had less aphids than the untreated control plots. Since few aphids were present when treatments were first applied, it is obvious that the DDT spray failed to check an increase in population. The formulation used was an experimental 25 per cent DDT spray powder with tobacco filler dust as diluent. It is difficult to determine whether the failure of DDT as a spray was a matter of poor formulation or of little or no residual effect.

All other treatments, DDT dust, parathion dust and spray, and combinations of both were equally effective in their control. It is possible that infestation at the time of treatment included both plant bed contamination and adult field migration, and that no subsequent migration occurred after the initial effect of both toxicants had become ineffective. It is also possible that both DDT and parathion were acting as repellents throughout the peak of infestation. In any case, it is interesting to note that the performance of DDT dust, was equal to that of parathion both in contact action and as a residue, if there was residual effect.

SUMMARY.—Thirty pounds of 10 per cent toxaphene dust or 10 per cent chlordane dust per acre applied to the surface of the soil at least a week before planting, gave excellent control of cutworms on tobacco. Toxaphene emulsion, at the same rate of active ingredient per acre, was equally effective. Chlordane, applied in the setting water at the rate of 4 oz. per 50 gal., and 30 lbs. of 10 per cent DDT dust per acre showed poor control of cutworms throughout the season.

DDT dust, parathion dust and spray, and combinations of both were very effective in controlling aphids when applied on tobacco as preventive treatments before heavy infestation occurs. A wettable DDT spray powder gave poor control of aphids.

LITERATURE CITED

Turner, Neely. 1949. Control of aphids on tobacco. JOUR. ECON. ENT. **42**(3): 561.

ROCKY MOUNTAIN CONFERENCE OF ENTOMOLOGISTS

The Rocky Mountain Conference of Entomologists will be held August 12, Noon to August 16, noon, at Cameron Pass, Colorado.

Entomologists and others who plan to attend should write Dr. George M. List for reservations and other information.

On Control of the Mexican Bean Beetle[1]

L. P. Ditman and Wm. E. Bickley, *College Park, Maryland*

During the past several years there have been numerous complaints from Maryland bean growers on the degree of Mexican bean beetle control secured with the available rotenone insecticides. Examination of bean fields by the authors revealed considerable inconsistency in results of commercial treatments, and some failures were caused by ineffective insecticide. Because of this dissatisfaction, a new project was initiated by the Maryland Experiment Station in 1949, and results of the first two seasons' work are here reported. These include results secured with several insecticides and combinations of insecticides in water sprays, liquefied gas aerosol formulations, and dust mixtures.

Aerosol Formulations: For convenience, the liquefied gas aerosol formulations used in the experiments are reported here and will be referred to later by number.

	Per Cent
Formula MD-3-49	
Parathion	2
Solvent[2]	10
Acetone	38
Methyl chloride	50
Formula MD-12-49	
Pyrethrum extract (20 per cent pyrethrins)	2.5
Oil[3]	10
Methylene chloride	37.5
Methyl chloride	50
Formula MD-7-50	
Test Material 1.[4] (25 per cent emulsion)	5.0
Methylene chloride	45
Methyl chloride	50
Formula MD-5-49	
Parathion	2
Xylol	10
Acetone	38
Methyl chloride	50
Formula MD-14-49	
Cube resin (33 per cent rotenone)	1.5
Acetone	48.5
Methyl chloride	50
Formula MD-8-50	
Compound 4049[5]	2
Acetone	48
Methyl chloride	50
Formula MD-9-50	
Compound 4124[6]	2
Acetone	48
Methyl chloride	50
Formula MD-10-50	
Cube resin (33 per cent rotenone)	1.5
n-propyl isome[7]	2
Acetone	46.5
Methyl chloride	50
Formula MD-12-50	
Methoxychlor	5
Cube resin (33 per cent rotenone)	1.5
Methylene chloride	43.5
Methyl chloride	50

1949 Experiments.—Six insecticidal treatments, including four aerosol formulations and 2 dust mixtures, were applied. The triumph variety of bush lima was used, and yields of beans were secured by use of a commercial type viner or sheller. The beans were planted in four-row plots 200 feet long on uniform soil and kept

[1] Scientific paper No. A301 contribution No. 2254 of the Maryland Agricultural Experiment Station, Department of Entomology.

[2] Velsicol AR-50, obtained from the Velsicol Corp. Chicago, Illinois.

[3] Deo-base oil, obtained from L. Sonneborn Sons, Inc., New York.

[4] Test Material #1 Obtained from Commercial Solvents Corp., New York. It contained a mixture of 2-nitro-1, 1 bis. (p-chlorophenyl) propane and 2-nitro-1, 1 bis. (p-chlorophenyl) butane.

[5] S-(1,2,-dicarbethoxyethyl) o, o-dimethyl dithio phosphate supplied by the American Cyanamid Co., N. Y.

[6] O-(2-chloro-4-nitrophenyl) o, o-dimethyl thiophosphate supplied by the American Cyanamid Co., N. Y.

[7] Di-n-propyl maleate-isosafrole, obtained from S. B. Penick and Co., N. Y.

Table 1.—Treatments and results of the 1949 experiments on Mexican bean beetle control. Treatments applied August 25, crop harvested September 12.

Treatment	Larvae (5) Scoops per Plot		Reduction Per Cent	Adults (5) Scoops per Plot		Shelled Beans per Plot, Pounds
	Aug. 25	Sept. 7		Aug. 25	Sept. 7	
Control	65	54	16.9	14	24	131.1
Aerosol: parathion MD-5-49	101	15	85.1	6	20	117.5
Aerosol: parathion MD-3-49	79	29	63.3	15	24	134.6
Dust: rotenone .25%, pyrethrins .05%, n-propyl isome .5%	114	3	97.3	18	3	150.0
Dust: parathion (.83%)	85	16	81.2	18	19	143.5
Aerosol: rotenone MD-14-49	111	38	65.8	30	15	124.9
Aerosol: pyrethrum MD-12-49	39	29	25.6	19	22	130.6

Table 2.—The nature of treatments applied and results of the 1950 experiments on lima beans. Treatments applied August 28, crop harvested September 14 (block 3) and Sept. 29 (blocks 1 and 2).

Treatments	Population Counts Eight Scoops per Plot						Shelled Beans per Plot, Pounds
	Adults		Per Cent Reduction	Larvae		Per Cent Reduction	
	Aug. 28	Aug. 31		Aug. 28	Aug. 31		
Aerosol: Test Material #1, MD-7-50	25	7	72.0	244	147	39.7	19.9
Aerosol: 4049 MD-8-50	9	9	—	274	194	29.2	22.7
Aerosol: 4124 MD-9-50	16	11	31.2	312	468	—	19.5
Aerosol: rotenone MD-10-50	7	14	—	204	210	—	16.8
Aerosol: parathion MD-5-49	14	8	42.8	322	106	67.1	19.4
Aerosol: methoxychlor MD-12-50	8	11	—	250	188	24.8	18.0
Dust: pyrethrins .05%, rotenone .25%, n-propyl isome .5%	19	11	42.1	304	20	93.4	19.8
Dust: parathion .83%	16	5	68.7	288	126	56.2	19.5
Dust: rotenone .75%	22	4	81.8	219	80	63.5	22.4
Spray: 4049 50% emulsion, 1 pt. per 100 gallon	19	10	47.3	235	164	30.2	16.3
Spray: 4049 25% wettable powder 1 lb. per 100 gal.	21	8	61.9	201	327	—	13.8
Spray: 4124 25% emulsion, 1 pt. per 100 gallon	15	16	—	329	427	—	17.3
Control	18	13	27.7	429	402	6.3	19.0

relatively free of weeds so that yield records are probably a better indication of insecticidal performance than the records of the light beetle population present. The nature of the treatments and results of observations are given in table 1. Single applications were made Aug. 25 at which time plants were blooming heavily. Aerosols were applied by a dispenser equipped with 3 gallon per hour oil burner nozzles, three nozzles per row, at a speed of 3 miles per hour or approximately 20 lbs. per acre. Dusts were applied with a small power duster at not less than 40 lbs. per acre.

Larval and adult populations were estimated by the scoop method. A metal scoop 24 inches wide is placed next to the row, and the insects are knocked into the scoop, immediately counted, and then dumped back onto the plants. While this method does not give the actual

Table 3.—Mexican bean beetle experiments on snap beans, 1950. Nature of treatments and observations on adult populations, based on a 5 scoop sampler per plot. Treatments applied August 16, 23, 31, and Sept. 6.

Treatment	Total Adults Before and After Each Treatment							
	Aug. 15	Aug. 18	Aug. 22	Aug. 25	Aug. 30	Sept. 1	Sept. 5	Sept. 8
Aerosol: T.M. #1, MD-7-50	137	56	60	27	18	10	9	5
Aerosol: 4049 MD-8-50	149	38	80	14	21	3	9	3
Aerosol: 4124 MD-9-50	140	94	87	45	30	17	16	14
Aerosol: rotenone MD-10-50	150	57	79	41	32	24	16	14
Aerosol: parathion MD-5-49	154	46	77	14	13	8	11	8
Aerosol: methoxychlor MD-12-50	175	71	86	56	31	13	20	10
Dust: rotenone .25%, Pyrethrins .05%, n-propyl isome .5%	158	34	78	14	19	5	6	1
Dust: parathion .83%	171	30	82	22	25	2	7	0
Dust: rotenone .75%	207	26	73	17	20	5	7	4
Spray: 4049 emulsion, 1 pt. in 100 gal. water	154	65	63	28	9	4	3	1
Spray: 4049 wettable powder 1 lb. in 100 gal. water	130	86	74	33	30	18	11	5
Spray: 4124 emulsion 1 pt. in 100 gal. water	162	138	79	70	36	22	16	15
Control	190	213	83	90	33	36	22	27

Table 4.—Mexican bean beetle experiments on snap beans 1950. Observations on larval populations based on 5 scoop samples.

Treatment	Total Larvae Before and After Each Treatment							
	Aug. 15	Aug. 18	Aug. 22	Aug. 25	Aug. 30	Sept. 1	Sept. 5	Sept. 8
Aerosol: TM #1, MD-7-50	18	10	0	3	1	0	2	1
Aerosol: 4049 MD-8-50	17	16	8	4	26	45	66	21
Aerosol: 4124 MD-9-50	15	26	30	18	79	217	319	291
Aerosol: rotenone MD-10-50	27	31	18	13	11	19	45	114
Aerosol: parathion MD-5-49	18	19	6	9	4	0	18	10
Aerosol: methoxychlor MD-12-50	20	19	7	14	17	37	71	71
Dust: rotenone .25%, pyrethrins .05%, n-propyl isome .5%	16	10	7	5	1	2	5	2
Dust: parathion .83%	33	19	5	3	0	8	4	2
Dust: rotenone .75%	17	10	0	1	3	0	1	0
Spray: 4049 emulsion 1 pt. in 100 gal. water	25	14	5	3	7	4	11	2
Spray: 4049 wettable powder 1 lb. in 100 gal.	26	16	17	8	10	29	58	33
Spray: 4124 emulsion 1 pt. in 100 gal. water	22	23	33	17	107	182	296	247
Control	13	46	38	39	97	268	294	251

number of individuals on plants, it does provide quickly a relatively accurate index of the larval and adult population intensity.

1950 LIMA BEAN EXPERIMENT.—Twelve insecticidal treatments were triplicated on two-row plots, 80 feet long, of the Fordhook 242 variety of bush lima beans. Estimations of larval and adult populations were made immediately before and 2 days after application of the insecticides. Because of wet weather, weeds were not as well controlled as in the preceding year nor was the soil as uniform, factors which contributed to considerable variation in yields. The nature of treatments and the results are given in table 2.

The high volume sprays were applied at 400 pound pressure with three potato type nozzles per row, equipped with No. 3 discs. Dusts were applied with a slightly larger duster than that used in 1949 and the rate of application was heavier than generally applied commercially. Attempts to calibrate the duster were unsuccessful.

1950 EXPERIMENTS ON SNAP BEANS.—The same treatments as applied to lima beans were applied to snap bean plots consisting of two 30-foot rows, each treatment being replicated 5 times. Four applications of all materials were made at weekly intervals. Two plantings of beans

Table 5.—Summary of observations on snap bean experiment, 1950.

Treatment	Per Cent Control Based on Sept. 8 Counts		Per Cent Injured Pods	Per Cent Reduction of Injured Pods
	Adults	Larvae		
Aerosol: TM #1, MD-7-50	81.5	99.6	2.6	83.6
Aerosol: 4049 MD-8-50	88.9	92.0	4.7	70.4
Aerosol: 4124 MD-9-50	48.1	—	10.2	35.8
Aerosol: rotenone MD-10-50	48.1	56.3	5.7	64.2
Aerosol: parathion MD-5-49	70.4	96.2	3.3	79.2
Aerosol: methoxychlor MD-12-50	63.0	72.8	6.0	62.3
Dust: rotenone .25%, pyrethrins .05%, n-propyl isomer .5%	96.3	99.2	2.5	84.3
Dust: parathion .83%	100	99.2	4.9	69.2
Dust: rotenone .75%	85.2	100	1.9	88.1
Spray: 4049 emulsion	96.3	99.2	4.4	72.3
Spray: 4049 wettable powder	81.5	87.4	6.1	61.6
Spray: 4124	44.4	5.4	9.2	42.1
Check			15.9	

were made, an early planting on which a heavy infestation was allowed to develop and a second planting at the time second generation adults began to emerge, the plots being placed between the plots of the first planting so as to provide equal exposure to the developing infestation, which became very heavy. Adult and larval counts were made by the scoop method the day preceding and two days following all treatments (Tables 3, 4, 5). Yields were not determined but the percentage of injured pods (Table 5) was determined on all plots (based on 200-pod random samples for each plot) immediately after the final treatments.

DISCUSSION AND SUMMARY.—In 1949 three out of six formulations killed over 80 per cent of the bean beetle larvae on lima beans. These were a parathion dust, a parathion aerosol, and a rotenone, pyrethrum, n-propyl isome dust. The last appeared to give a higher kill of adults and gave a better yield of shelled beans than other treatments.

In the 1950 experiments the rotenone, pyrethrum, n-propyl isome dust was the most effective of 12 treatments against larvae on lima beans. On snap beans, after four applications, a reduction in larval population of over 90 per cent was brought about by rotenone, pyrethrum, n-propyl isome dust; straight rotenone dust; parathion dust and aerosol; compound 4049 emulsion and aerosol; and TM #1 aerosol. Based on reduction in number of injured pods these same seven formulations gave the best results, and they likewise performed well in reducing adult populations. A repellency factor is doubtless present in some of the substances so that adult mortality is difficult to measure.

Bis-(*p*-Chlorophenoxy)-Methane in Relation to the Control of Citrus Red Mite and Other Mites Injurious to Citrus in California[1]

L. R. JEPPSON,[2,3] *University of California Citrus Experiment Station, Riverside*

Five species of mites cause sufficient injury to citrus trees or fruit in California to justify chemical control measures, namely, the citrus red mite, *Paratetranychus citri* (McG.), the six-spotted mite, *Tetranychus sexmaculatus* Riley, the Lewis mite, *Tetrancyhus lewisi* McG., the citrus bud mite, *Aceria sheldoni* (Ewing), and the citrus rust mite, *Phyllocoptruta oleivora* (Ashm.).

CONTROL OF THE CITRUS RED MITE.—As a pest of citrus in California, the citrus red mite has become second in importance only to the California red scale, *Aonidiella aurantii* (Mask.). Citrus groves located in the coastal sections of the state may become seriously infested with this mite at any time of the year. Groves in Riverside, San Bernardino, and eastern Los Angeles counties generally receive the most injury from the citrus red mite in the spring. In these sections the populations are reduced by the hot, dry summer conditions, and treatment is usually not necessary until the following fall. Petroleum oil is the principal material used to control the citrus red mite, the California red scale, and the citrus bud mite. Because there are conditions in citrus culture under which it is inadvisable to use petroleum oil sprays (Boyce 1948), there has been an urgent demand for materials other than petroleum oils for mite and scale control.

Boyce *et al.* (1939) developed dust and spray formulations of dinitro-o-cyclohexylphenol which have been used extensively for citrus red mite control under conditions that appear unfavorable for the application of petroleum oil. Two formulations of the dicyclohexylamine salt of dinitro-o-cyclohexylphenol are used on citrus, namely,—a dust which contains 1.5 per cent and a wettable powder which contains 20 per cent of the salt of this DN material.[4] These formulations have not generally been so effective as petro-

[1] Paper No. 665, University of California Citrus Experiment Station, Riverside, California.

[2] Assistant Entomologist in the Experiment Station.

[3] The author wishes to thank all those who have cooperated in these studies, to acknowledge particularly the very able assistance of M. J. Jesser and J. O. Complin, and to express appreciation to the Dow Chemical Company for making available adequate supplies of *K-1875*.

[4] Both of these products manufactured by The Dow Chemical Company.

leum oil sprays in controlling the citrus red mite. During the past few years unsatisfactory mite control has been obtained with both experimental and commercial applications of these materials. When *DN Dust* or wettable powder has been applied immediately preceding periods of hot weather, plant injury has often occurred. As these dusts and sprays have given more effective mite control during warm weather than during colder intervals, the margin of safety between effective control and plant injury has been relatively narrow. Because of these conditions and the general importance of the citrus red mite, other materials have been evaluated for its control. Bis-(*p*-chlorophenoxy)-methane, hereinafter referred to as *K-1875*,[1] was sufficiently promising to warrant extensive studies.

Jeppson (1947) has reported results of initial laboratory and field studies with *K-1875* for control of the citrus red mite, *Paratetranychus citri* (McG.). In laboratory studies Metcalf (1948) found *K-1875* to be about 40 times as toxic to *P. citri* as to *Tetranychus bimaculatus* Harvey. Armstrong (1950) found *K-1875* applications at 1 pound per 100 gallons of spray to be highly toxic to all stages of the two-spotted spider mite, *T. bimaculatus*, for one week after treatment but relatively nontoxic after two weeks. Sherman & King (1948) reported ineffective control of *T. bimaculatus* on peaches.

Hough (1948) states that *K-1875* ranked among the most effective compounds evaluated against a mite population of which 94 per cent were European red mites, *Paratetranychus pilosus* (C. & F.), and the remaining individuals were mostly *Septanychus schoenei* (McG.). Newcomer & Dean (1948, 1949) reported that *K-1875* was fully as effective as parathion against the European red mite, but was less effective against the Pacific mite, *T. pacificus* McG., and was not considered sufficiently effective when used with DDT in summer sprays for control of either species of mites. Barnes* obtained good commercial control of European red mite on Delicious apple trees with *K-1875* when used in preventive sprays at 8 ounces and 1 pound per 100 gallons of water; however, these treatments caused russeting of the fruit. He reported unsatisfactory control of the clover mite, *Bryobia praetiosa* Koch, and the Pacific mite at 1-pound dosages in a two-application program. According to Newton & List (1949), spotting of apples as well as inadequate control of clover mite resulted when this material was applied. Iglinsky & Gaines (1949) obtained ineffective control of *Septanychus* sp. on cotton with *K-1875*. Spencer *et al.* (1950) described some of the chemical and physical properties of *K-1875* and reported results of toxicological studies on warm-blooded animals.

General Plan of Experiments and Methods of Evaluating Results.—The size of the plots used in these experiments varied according to the condition of the grove and the method of application of *K-1875*. Unless otherwise noted, the spray plots were sufficiently large to allow for a border row of untreated trees on each side of the test trees. Two border rows were allowed when applications were made by boom-sprayer or spray-duster equipment, and four were allowed when dusts were applied.

Each type of application equipment used has been described and figured by Boyce (1948). Manual (conventional) applications of *K-1875* were made with high-pressure spray equipment at approximately 1600 gallons per acre on average-sized orange trees.

The citrus red mite infestations were sampled prior to treatment, and the rate of reinfestation was evaluated by sampling the population at periodic intervals. It has been observed that full-sized, immature citrus leaves are more favorable for citrus red mite infestation than old or very young leaves. In order to sample leaves somewhat uniformly favorable for mites, four leaves near the tip of a terminal were used as a sample unit. The adult mites on eight units per tree were counted, and a rating was assigned according to the total number of mites found on each tree. Tree ratings from eight trees per plot were averaged to obtain the population index used in the tables and charts of this paper as the basis for comparing the relative mite density following field acaricidal treatments. The population index and relative degree of field infestation are correlated as follows:

[1] Throughout this paper, reference is to technical *K-1875*. A 40 per cent air-milled wettable-powder formulation is marketed by The Dow Chemical Company under the trade name *Neotran*.

* Paper in preparation, 1951.

MITE POPULATION INDEX	DEGREE OF FIELD INFESTATION
1	Trace
2 to 5	Light
5 to 10	Light-Medium
10 to 20	Medium

Growers who keep the citrus red mite injury to a minimum apply treatment before a medium infestation occurs. Rates of reinfestation of groves receiving a given treatment, but in different localities or at different seasons of the year, are not comparable. The temperature, humidity, abundance, and activity of natural enemies, and the conditions of the leaves and fruit, as well as many other factors which occur during and/or after treatment may influence the rate at which treated groves become reinfested.

A satisfactory chemical method of estimating amounts of *K-1875* residues has not been developed. It was therefore necessary to estimate amounts of both laboratory and field residues by means of biological assays. The toxicity of field residues of *K-1875* was evaluated in the following manner. At the desired interval after treatment one fruit was selected from each quadrant of each of four trees in each plot. These fruits were brought into the laboratory, and 25 adult female citrus red mites were placed on each one. The infested fruits were held at 80° F. and 80 per cent relative humidity for 48 hours, and mite mortality was then determined.

Several methods of preparing *K-1875* spray and dust formulations were utilized in the various phases of this study. Emulsion formulations were prepared by dissolving the *K-1875* in kerosene, tetralin, or a dimethylnaphthalene solvent.[1] Kerosene emulsion formulations used in initial studies were prepared by dissolving 4 parts by weight of *K-1875* in 1 part of the dimethylnaphthalene solvent and 12 parts kerosene, emulsified with 4 ounces of blood-albumin spreader in 100 gallons of water. Three different methods were used in preparing the wettable powders and dust formulation concentrates: they were (1) solvent-impregnated, (2) hammer-milled, or (3) air-milled. The solvent-impregnated formulations were made by dissolving the *K-1875* in xylene and atomizing the solution on an appropriate diluent[2] in a ribbon blender. In preparing the hammer-milled and air-milled formulations, *K-1875* was mixed with the diluent and milled to small particle size. The distribution of particle sizes of these formulations is summarized in table 1.

Table 1.—Particle size of hammer-milled and air-milled *K-1875* formulations.

DIAMETER RANGE OF PARTICLES, IN MICRONS[1]	PERCENTAGE OF PARTICLES IN EACH SIZE RANGE	
	Air-Milled	Hammer-Milled
0.25– 1.75	64	10.5
1.76– 3.5	26	28.0
3.6 – 9.0	8	43.0
9.1 –50.0	2	18.5
Average diameter, in microns	1.85	6.6

[1] Estimated by microscopic examination.

Formulation Experiments.—Laboratory and field tests indicate not only that *K-1875* was toxic to young and adult mites at the time of application, but also that the spray residues remained toxic for several weeks (Metcalf 1948, Jeppson 1947). Spray formulations of *K-1875* dissolved in kerosene, xylene, tetralin, or the dimethylnaphthalene solvent were found to be toxic to eggs of the red mite. In the initial field studies, *K-1875*—dimethyl naphthalene—kerosene emulsion formulations were compared with a spray containing 1.75 per cent medium emulsive petroleum spray oil (Marshall 1932, Erb 1932) for the control of citrus red mite.[3] In 12 of the 19 groves where these formulations were applied under comparable conditions, there was no appreciable difference between *K-1875* and petroleum oil in the control of citrus red mite. In 3 of the experimental groves better control resulted in the oil-treated plots, and in 4 groves more effective control was obtained where the formulation of *K-1875* was applied. These results indicate that the *K-1875*—dimethylnaphthalene solvent—kerosene formulations compared favorably with the conventional oil treatments used at present for the control of the citrus red mite.

[1] *Velsicol AR-60;* Velsicol Corporation, Chicago, Ill.
[2] *Diluex* was used in these studies. Manufactured by the Floridin Co., Inc., Warren, Pennsylvania.
[3] Since petroleum oil is used most extensively for citrus red mite control, it was utilized in the initial studies as a standard of field comparison for citrus red mite control on lemons.

In order to evaluate the comparative effectiveness of emulsion and wettable-powder formulations in the control of citrus red mite under a wide variety of field conditions, applications of each of these formulations were made on 14 groves. In these studies the *K-1875*—dimethylnaphthalene—kerosene emulsion previously described was compared with a 40 per cent *K-1875* hammer-milled wettable-powder preparation. The materials were applied by conventional spray methods, using 1 pound *K-1875* per 100 gallons of water.

In these studies the wettable-powder formulations resulted in as efficient field control of the citrus red mite as the emulsion formulations, even though laboratory studies and field observations indicated that the emulsion preparations effected a higher percentage kill of the mite eggs. Field observations showed considerable mortality of the mite eggs from the sprays containing *K-1875* wettable powders, and deposits from these sprays generally remained sufficiently toxic to kill most of the young mites that hatched from eggs present at the time of treatment. In extensive field studies there was no appreciable difference in control of citrus red mite with spray applications of formulations prepared from hammer-milled, air-milled, or solvent-impregnated concentrates. Hammer-milled concentrates resulted in the most effective dust formulations, however.

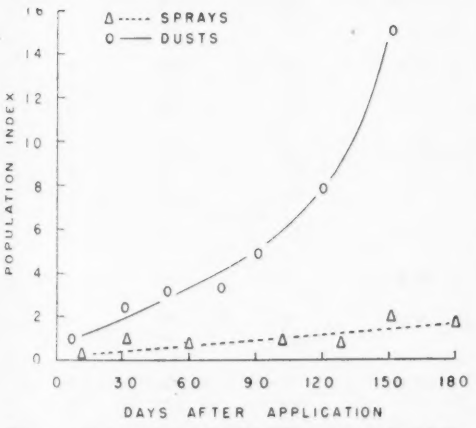

FIG. 1.—Comparative effectiveness of *K-1875* dusts and sprays when applied by spray-duster equipment for control of the citrus red mite. Each point on the chart represents the mean from eight plot replications of eight trees per plot.

Application Experiments.—No available equipment for applying *K-1875* has resulted in more consistent control of citrus red mite than the conventional hand spray. Under a wide variety of conditions, however, more rapid methods of application with other equipment have resulted in as effective control as the conventional sprays. Applications of *K-1875* at approximately 1600 gallons per acre by mechanical oscillating boom sprayers have ordinarily resulted in satisfactory citrus red mite control on lemons. Experimental applications of *K-1875* made with air-blast equipment such as spray-dusters or speed sprayers were effective where 100 to 500 gallons of spray were applied per acre, provided that the spray was adequately distributed on the trees.

In experimental studies with spray-duster applications of *K-1875*, an increase in the volume of water over 100 gallons per acre did not increase the effectiveness of the spray. For adequate distribution of less than 200 gallons of spray per acre for citrus red mite control, disc orifices smaller than 0.047 inch in diameter should be used. As these small orifices readily become obstructed when *K-1875* wettable powder is applied, commercial spray operators have generally used 200 to 500 gallons of spray per acre with this equipment.

Several pest control operators have obtained satisfactory control of the citrus red mite with *K-1875* by adapting non-oscillating boom equipment to distribute a mist-type spray to all sections of the

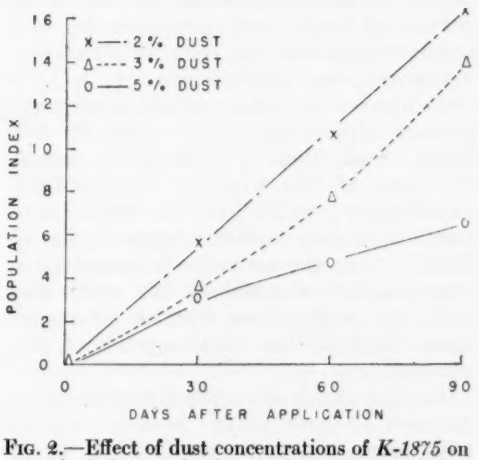

FIG. 2.—Effect of dust concentrations of *K-1875* on control of citrus red mite, as shown by population index under field conditions.

trees. With this type of equipment, 400 to 500 gallons of spray were applied per acre at 650 to 700 pounds pressure.

The spray-duster equipment, which is designed to apply either dusts or semi-concentrate sprays, offered an opportunity to evaluate the relative effectiveness of each of these two types of *K-1875* formulations. In these studies a dust mixture composed of 4 per cent *K-1875* and 96 per cent pyrophyllite was applied at 100 pounds per acre. For the sprays a 40 per cent hammer-milled wettable-powder formulation was used at the rate of 10 pounds in 200 gallons of water per acre. As shown in figure 1, the spray applications gave more effective control of citrus red mite than the dust treatments.

Studies on 2, 3, and 5 per cent dust concentrations were made in 10 groves. These dusts were made from hammer-milled formulations of *K-1875* and were applied with the spray duster at 100 pounds per acre. The mite populations were evaluated 2, 30, 60, and 90 days after treatment. The results of these studies (Fig. 2) show a direct increase in efficiency of the dust with increase in concentration of *K-1875* from 2 to 5 per cent.

The value of oil as a means of increasing the amount and improving the adhesion of the deposit of *K-1875* dusts was investigated. The efficiency of formulations impregnated with 2 per cent mineral oil[1] was evaluated under a variety of field conditions. When *K-1875* dusts with and without oil were evaluated under similar conditions in eight field experiments, no improvement in the control of citrus red mite was obtained by the addition of oil to the dust formulations.

Concentrate applications of *K-1875* were applied by heat and high-pressure aerosol applicators, such as the Beskil, Todd, and Banta Driscoll machines. Solutions of this material in dimethylnaphthalene, xylene, or kerosene were used in these studies. Applications of *K-1875* with the aerosol equipment gave unsatisfactory control of the citrus red mite, the applications resulting in inadequate distribution and deposit of the material.

Residue and Weathering Experiments.—In each of three groves heavily infested with citrus red mite, applications of 40 per cent air-milled wettable-powder formulations of *K-1875* were made by conventional spray equipment at four to six dosage levels ranging from 2.4 to 20 pounds of technical material per acre. Two replicates of each dosage were applied to plots two trees wide and six trees long. At 7-day intervals the relative tox-

Table 2.—Relation of dosage and interval after application to weathering of *K-1875* residue on fruit surface and toxicity to the citrus red mite in three Valencia orange groves.

K-1875 Applied (Pounds per Acre)	Days After Treatment	Per Cent Mortality of Mites	*K-1875* Residue (Mg. per Sq. Cm.)[1]
	Grove A		
4.0	7	61	1.1
	14	18	0.5
	21	10	0.4
6.0	7	69	1.2
	14	27	0.6
8.0	14	50	1.0
	21	22	0.6
12.0	7	100	2.5+
	14	82	1.5
	21	63	1.2
20.0	14	100	2.5+
	Grove B		
2.4	14	29	0.7
	28	10	0.4
3.6	14	73	1.4
	28	20	0.6
4.8	14	81	1.5
	28	24	0.6
	42	10	0.4
7.2	14	93	2.3
	28	79	1.4
9.6	14	100	2.5
	28	81	1.5
	42	39	0.7
12.0	14	100	2.5+
	28	89	1.8
	42	41	0.8
	Grove C		
4.0	14	15	0.5
6.0	7	80	1.5
8.0	7	93	2.3
	14	77	1.4
12.0	7	100	2.5+
	14	100	2.5+

[1] Estimated from percentage mortality data by means of Metcalf's mortality curve (Fig. 4).

[1] Viscosity, 107 S.S.U. at 100° F.; unsulfonated residue, 70 per cent.

icity of the residues resulting from each dosage level was evaluated by biological assay. The results of these assays are reported in table 2. The relations of dosages applied and periods of weathering to percentages of mortality in two groves are graphically illustrated in figure 3 (A and B). The average daily maximum and minimum temperatures and the total rainfall in these groves during each weathering period were as follows:

Period, in Days	Average Daily Temperature, °F.		Total Rainfall, Inches
	Maximum	Minimum	
	Grove A		
7	75	45	0
14	77	43	0
21	73	41	0.19
	Grove B		
14	60	34	2.28
28	60	34	1.07
42	58	35	0.68

Metcalf[10] has estimated the relationship of dosage, in micrograms of *K-1875* per square centimeter of fruit surface, to mortality of adult female citrus red mite (Fig. 4). This mortality curve was used by the author to estimate the amount of *K-1875* residue present on field fruit samples. In table 2 the percentage mortality values obtained from these field and laboratory studies are interpreted by means of Metcalf's curve.

To ascertain the rate at which the plots receiving each dosage became reinfested, field populations of citrus red mites were estimated at five different intervals after treatment. These estimates are presented in table 3 as population indexes. The population indexes from groves A, B, and C, 175, 140, and 105 days, respectively, after treatment, are plotted in figure 5 in order to illustrate more clearly the influence of dosage on mite control, as measured at a given interval after application.

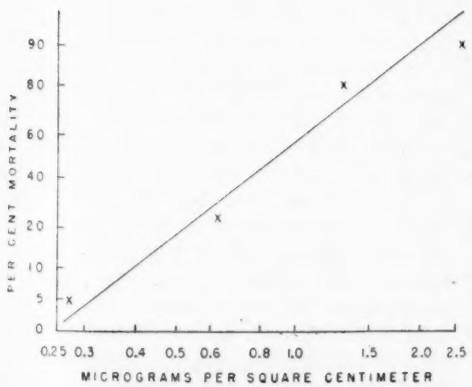

FIG. 4.—Logarithmic relationship of *K-1875* residues per unit area of fruit surface to mortality of adult female citrus red mite. (From R. L. Metcalf data, unpublished.)

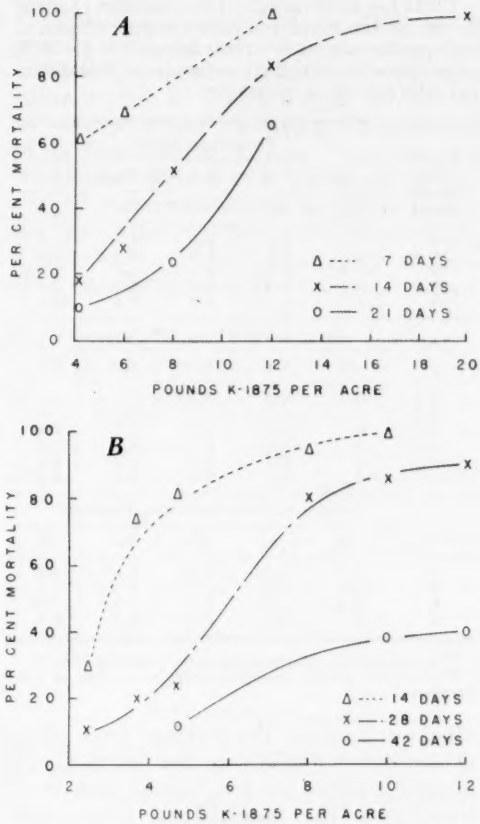

FIG. 3.—Influence of various dosages of *K-1875* and periods (days) of weathering on the toxicity of the residue to adult female citrus red mites in two citrus groves (A and B).

Relations between *K-1875* spray residues and citrus red mite control exhibited in these experiments may be summarized as follows: (1) Residues from field applications of *K-1875* persisted on the fruit and caused mortality of citrus red mites for several weeks after treatment, but the percentage mortality became less each succeeding week. (2) At a given interval

[10] Unpublished data on file at the University of California Citrus Experiment Station, Riverside.

Table 3.—Relative rate of reinfestation of citrus groves by the citrus red mite after treatment of high populations with various dosages of *K-1875;* populations in each grove estimated at five different intervals after treatment.

K-1875 Applied (Pounds Acre)	Population Index[1]				
	Grove A, Given Days After Treatment				
	70	104[2]	132	153	175
4	3.7	0.8	2.6	6.3	11.4
6	1.7	0.6	1.4	4.0	8.9
8	0.8	0.1	0.5	1.6	3.9
12	0.1	0.1	0.6	1.4	1.6
20	0	0	0.3	1.2	0.6
	Grove B, Given Days After Treatment				
	34	126	140	168[2]	191
2.4	0.1	10.1	13.0	re-treated	—
3.6	0	5.8	9.7	re-treated	—
4.8	0	4.0	5.3	5.5	5.5
7.2	0	1.2	3.5	3.5	5.4
9.6	0	0.1	1.7	2.0	4.8
12	0	0	0.6	2.0	4.8
	Grove C, Given Days After Treatment				
	36	80	80[2]	105	136
4	1.3	3.5	3.0	4.8	5.8
6	4.0	7.0	5.5	5.5	3.7
8	0.4	0.7	1.8	3.6	3.5
12	0	0	0.2	3.0	2.3

[1] For explanation of "population index" refer to text.
[2] Unfavorable weather conditions retarded the rate of reinfestation.

after application, the residues from plots in each grove receiving the same initial dosage resulted in a different degree of toxicity to the mites. It is likely that climatic conditions during the progress of the experiments influenced the rate at which the deposits weathered. The influence of temperature on the residual toxicity of *K-1875* deposits to citrus red mite is discussed later in this paper. (3) The amount of *K-1875* applied per acre was an important factor in determining the length of time the residue was present and toxic to adult female citrus red mites. As the amount of *K-1875* applied per acre was increased from 4 to 12 pounds (Table 2 and Fig. 3, A, and B), the interval after treatment that the resulting residues were toxic to a given percentage of mites was increased. (4) There was a positive correlation between the dosage applied per acre, the length of time residues were present and toxic to mites, and the effectiveness of the control resulting from the applications. (Compare results shown in table 2, groves A, B, and C, with those of table 3, groves A, B, and C.) As the dosage was increased up to 12 pounds per acre, there was not only an increase in the time the residues were present and toxic to adult mites, but also more effective field control.

In field studies, temperature conditions following applications of *K-1875* appeared to be an important factor in determining the rate at which the deposits lost their toxicity to citrus red mite. Results given in table 2 indicate differences in the residue present on fruit from three groves, A, B, and C, when sampled at given intervals after treatment. The estimated amount of residue remaining on the fruit surface in each grove 14 days after treatment was plotted in relation to the dosage applied per acre. It will be observed from the resulting curves (Fig. 6) that more

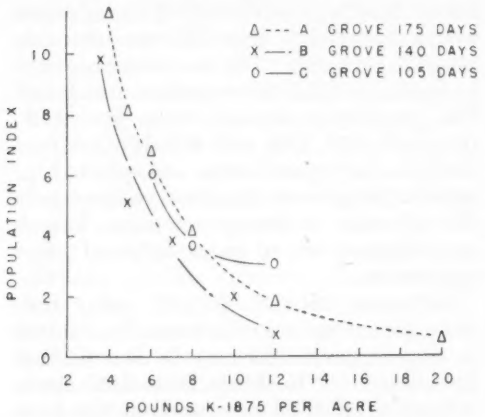

FIG. 5.—Relation of dosage of *K-1875* to the control of citrus red mite, as shown by population index under field conditions. Grove A was treated November 15, 1948; grove B, December 15, 1948; and grove C, March 15, 1949. Least significant differences required (at 19:1), 2.0, 1.7, and 1.3, respectively.

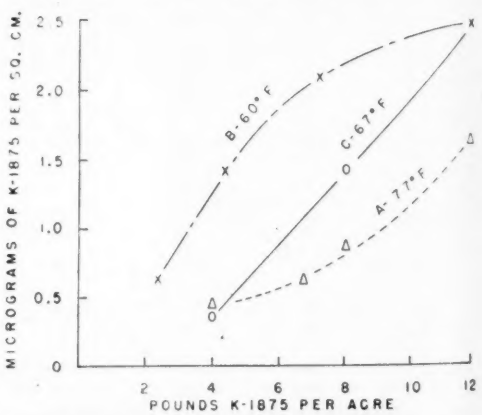

FIG. 6.—Relation of temperature and dosage (pounds *K-1875*) to the amount of residue (micrograms *K-1875*) on Valencia orange fruit in groves A, B, and C 14 days after treatment.

residue persisted on the fruit when the temperature was relatively low (60° F.) than when higher temperature conditions prevailed (67° and 77° F.).

To evaluate this point further, the rates at which deposits weathered during the periods August 27 to September 10, when the average of the maximum temperatures was 88° F., and December 15 to January 22, when the average of the maximum temperatures was 72° F., were determined by biological assay. Results are summarized in figure 7. The percentage of mite mortality resulting

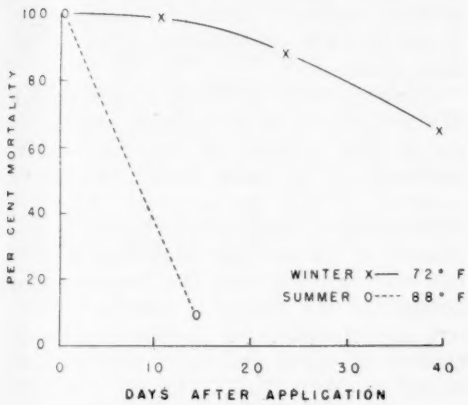

FIG. 7.—Percentage mortality of citrus red mites on lemon fruits having *K-1875* deposits weathered in the field at an average maximum temperature of 88° F. from August 27 to September 10, and of 72° F. from December 15 to January 22.

after *K-1875* deposits had weathered 14 days at the higher temperature (88° F.) was less than 20 per cent, whereas at the lower temperature (72° F.) the residues were toxic to more than 60 per cent of the mites after weathering for 40 days.

To ascertain the influence of various constant temperature conditions on control of the citrus red mite with *K-1875*, the following procedure was employed. Grapefruits were precision-sprayed in the laboratory with a small-capacity spray apparatus having a high-pressure, reciprocating-type pump, using 1.5 pounds (per 100 gallons of water) of 40 per cent *K-1875* formulated as an air-milled wettable powder. Fifty treated fruits and 25 untreated fruits were placed in each temperature cabinet. The average temperatures in the cabinets were 88°±1.5°, 80°±2.5°, 70°±1.5°, and 60°±1.5° F., respectively. At intervals of 2, 4, 8, 16 and 32 days, 10 treated fruits and 5 untreated fruits were removed from each cabinet and 25 adult female citrus red mites were placed on each fruit by means of a camel's-hair brush. The infested fruits were held for 48 hours at 75° F. and 75 per cent relative humidity before the percentage mortality was ascertained. The results of these laboratory studies (Fig. 8) indicate that *K-1875* residues lost

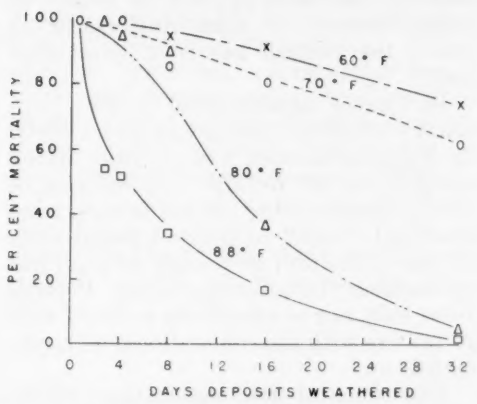

FIG. 8.—Relation of temperature to toxicity of residues from an air-milled powder formulation of *K-1875* to citrus red mites under laboratory conditions.

their effectiveness in killing adult female citrus red mites more rapidly as the temperature was increased from 60° to 88° F. It will be noted that the residues were more toxic 32 days after application at 70° F. than they were 2 days after application at 88° F. The results of both field and laboratory studies indicate that temperature is a major factor in the weathering of *K-1875* residues. Commercial use of a proprietary preparation of Bis-(*p*-chlorophenoxy)-methane)[1] for the past 18 months has indicated that more erratic citrus red mite control has resulted from applications in the late spring and summer than at other seasons. Citrus red mite control with this preparation has not been so effective in the more interior areas as in the cooler coastal districts.

CONTROL OF OTHER MITES INJURIOUS TO CITRUS.—It is difficult to bring acaricides into contact with the six-spotted mite, *Tetranychus sexmaculatus* Riley, in

[1] A 40-per cent air-milled wettable powder formulation of Bis-(p-chlorophenoxy)-methane.

the field, as these mites develop in colonies on the undersides of the citrus leaves. When the leaf is viewed from the underside, the mites and their eggs are in depressions covered by fairly heavy webbing. Spray applications of *K-1875*, made with sufficient coverage with conventional hand-spray equipment to insure contact with the colonies in the depressions on the undersides of the leaves, have resulted in satisfactory control of this mite. When this material has been applied by means of boom sprayers or spray-dusters, or as dusts, the control has been unsatisfactory.

In limited experimental studies, seasonal control of *Tetranychus lewisi* McG. on Valencia oranges resulted from spring applications of *K-1875*. Applications of *K-1875* made during the fall season, however, have failed to prevent populations of this mite from increasing to injurious proportions the following spring. Populations were not so effectively reduced with *K-1875* as with the conventional oil applications.

Experimental field applications of *K-1875* have not effectively reduced field populations of either the citrus bud mite, *Aceria sheldoni* (Ewing), or the citrus rust mite, *Phyllocoptruta oleivora* (Ashm.). Results indicate that this compound is not sufficiently toxic to these eriophyid mites under field conditions to effect even a good initial kill.

PHYTOTOXICITY OF *K-1875*.—This material has been applied in many formulations under a wide variety of climatic conditions in studies on control of mites on citrus. No injury to citrus foliage or fruit has been observed as a result of the applications. Among these formulations have been included the following: (a) 2 pounds of *K-1875* in 1 quart dimethylnaphthalene and 3 gallons of kerosene, emulsified with blood-albumin spreader in 100 gallons of water and applied at approximately 1600 gallons per acre; (b) 1 pound of *K-1875* applied with the conventional petroleum oil sprays; (c) 20 pounds of *K-1875* formulated as a 40 per cent wettable powder and applied at 200 gallons of spray per acre; and (d) 20 pounds *K-1875* as a 25 per cent emulsive formulation in xylene, applied at 3 gallons per acre by heat and high-pressure aerosol applicators.

In the experiment designed to ascertain the amount of *K-1875* required to produce tree or fruit injury, a 40 per cent wettable-powder formulation was applied at the very high dosage of 4 pounds *K-1875* per 100 gallons of water. This spray formulation was applied at the rate of 1500 gallons per acre in the summer when the temperature each of the 10 days immediately following application reached 95° F. or above. A slight pitting occurred on the undersides of the young lemon leaves. No injury was observed on mature lemon leaves or fruit or on orange or grapefruit trees or fruit. *K-1875* has been under commercial use on thousands of acres of citrus. No injury attributable to the *K-1875* applications to citrus has been reported.

COMPATIBILITY OF *K-1875* WITH OTHER MATERIALS.—It is a common practice in citrus pest control to combine several materials in the same spray mixture in order to achieve two or more objectives with one spray application. Under experimental or commercial conditions *K-1875* has been applied with the recommended dosages of the following materials without appreciable loss in effectiveness in control of citrus red mite and without injury to citrus fruit or foliage: zinc sulfate, zinc oxide, manganese sulfate, soda ash, sulfur, cryolite, nicotine sulfate, rotenone, and 2,4-dichlorophenoxy acetic acid.

The inclusion of hydrated lime in the spray mixture containing *K-1875* has affected the physical properties of the spray, so that a clogging of the screen and nozzles of the spray equipment occurs.

The addition of DDT to applications of *K-1875* did not appear to reduce the immediate effectiveness of the *K-1875* treatments in the control of citrus red mite, but the mite populations increased more rapidly whenever DDT was incorporated in the spray. This reaction was not attributed to incompatibility of the DDT and *K-1875* but to the influence of DDT on beneficial insects or the physiology of the mite-host relationship or both.

SUMMARY.—The relatively new acaricide, bis-(*p*-chlorophenoxy)-methane (*K-1875*), was studied in relation to its effectiveness in the control of five species of mites injurious to citrus in California.

A formulation containing 1 pound of technical *K-1875* dissolved in dimethylnaphthalene-kerosene mixture and emulsi-

ied with blood-albumin spreader was as effective in control of citrus red mite, *Paratetranychus citri* (McG.), as the conventional petroleum oil sprays.

No measurable difference in the control of citrus red mite was found when *K-1875* was formulated as an emulsion or as a wettable powder.

The most consistent results were obtained with conventional spray applications of *K-1875;* however, under many field conditions equally effective applications were made more rapidly by means of spray-duster, speed-sprayer, or boom-spray equipment. *K-1875* dust applications were less effective in citrus red mite control than sprays, when applications of equal dosages per acre were made. The addition of 2 per cent oil as an adhesive agent in *K-1875* dusts did not improve their effectiveness, and concentrate or fog applications of *K-1875* were not effective.

As the amount of *K-1875* applied per acre to Valencia orange trees was increased from 4 to 6, 8, 10, and 12 pounds per acre, the length of time the residues were present and toxic to the citrus red mite was increased, as was also the effectiveness of the control.

In laboratory and field experiments high temperatures increased the rate at which *K-1875* deposits lost their toxicity to citrus red mite.

K-1875 has been found to vary in its toxicity to mites of the Tetranychidae. On citrus it was effective only under restricted conditions to the six-spotted mite, *Tetranychus sexmaculatus* Riley, and the Lewis mite, *Tetranychus lewisi* McG., and it was found to be ineffective in the control of the citrus bud mite, *Aceria sheldoni* (Ewing), and the citrus rust mite, *Phyllocoptruta oleivora* (Ashm.).

Plant injury to citrus has not been observed from *K-1875* as the result of either experimental or commercial applications, except at unnecessarily high dosages.

LITERATURE CITED

Armstrong, Thomas. 1950. The residual toxicity of some newer acaricides to the two-spotted spider mite (*Tetranychidae*). Acarina: Canad. Ent. **82**(4): 73–83.

Barnes, M. M. 1951. Studies with acaricides for control of mites on apples and pears in southern California. (In preparation.)

Boyce, A. M. 1948. Insects and mites and their control. Chapter XIV (pp. 665–812) *in*: Batchelor, L. D., and H. J. Webber (eds.), *The Citrus Industry*, vol. II. University of Calironia Press, Berkeley and Los Angeles.

Boyce, A. M., D. T. Prendergast, J. F. Kagy, and J. W. Hansen. 1939. Dinitro-o-cyclohexylphenol in the control of mites on citrus and Persian walnuts. JOUR. ECON. ENT. **32**(3): 450–67.

Dow Chemical Company. 1947. Neotran (K-1875) a new acaricide. Technical Service and Development Division, The Dow Chemical Company, Midland, Michigan. 5 p. (Processed.)

Ebeling, Walter. 1947. DDT preparations to control certain scale insects on citrus. JOUR. ECON. ENT. **40**(5): 619–32.

English, L. L., and G. F. Turnipseed. 1941. The influence of temperature and season on the citrus red mite (*Paratetranychus citri*). Jour. Agr. Res. **62**(2): 65–77.

Erb, L. W. 1932. Analyses of oil spray emulsions and spray oils. Chart No. 4. California Dept. Agr., Div. Chem. 1 p. California State Printing Office, Sacramento, California.

Hough, W. S. 1948. Control of mites on apple trees sprayed with DDT. JOUR. ECON. ENT. **41**(2): 207–9.

Iglinsky, Wm., Jr., and J. C. Gaines. 1949. Tests of insecticides to control red spider mites. JOUR. ECON. ENT. **42**(4): 703–5.

Jeppson, Lee R. 1947. Di(4,chlorophenoxy) methane for control of citrus red mite. JOUR. ECON. ENT. **39**(6): 813.

Metcalf, Robert L. 1948. Acaricidal properties of organic compounds related to DDT. JOUR. ECON. ENT. **41**(6): 875–82.

Moulton, Dudley. 1932. Economic poison decisions. *In*: Economic poisons 1931–32. California Dept. Agr. Spec. Pub. **116**: 7–8.

Newcomer, E. J., and F. P. Dean. 1948. Studies of orchard acaricides. JOUR. ECON. ENT. **41**: 691–4.

Newcomer, E. J., and F. P. Dean. 1949. Comparative effectiveness of orchard acaricides. JOUR. ECON. ENT. **42**(5): 857–8.

Newton, J. H., and G. M. List. 1949. Codling moth and mite control in 1948. JOUR. ECON. ENT. **42**(2): 346–8.

Sherman, Franklin, III, and H. L. King. 1948. Tests in 1947 against the two-spotted spider mite. JOUR. ECON. ENT. **41**(5): 807–8.

Spencer, H. C., V. K. Rowe, E. M. Adams, and D. D. Irish. 1950. Toxicologic studies on the new miticide bis(parachlorophenoxy)methane. I. Acute and semichronic toxicity. Arch. Indus. Hyg. Occup. Med. **1**: 341–7.

Repellents and Insecticides Available for Use Against Insects of Medical Importance[1,2]

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The need for an effective mosquito repellent for the protection of troops against mosquito-borne diseases led to intensive research on this problem in the United States and elsewhere beginning early in World War II. Many thousand materials, a large portion of which were new organic compounds especially synthesized for this purpose in various laboratories, were tested, and at the Orlando, Fla., laboratory of the Bureau of Entomology and Plant Quarantine several hundred were found that were much more effective than citronella and other essential oils used previously. These promising compounds were subjected to toxicological tests, and the ones that appeared safe for use on the skin were evaluated in the field against different species of mosquitoes and other biting flies.

Two of the best repellents that came to light fairly early in the work were Rutgers 612 (2-ethyl-1, 3-hexanediol), first reported by Granett & Haynes (1945) and dimethyl phthalate, which had been incorporated into a commercial repellent lotion. Rutgers 612 was especially effective against the yellow-fever mosquito, *Aëdes aegypti* (L.), and a salt-marsh species, *A. taeniorhynchus* (Wied.), whereas dimethyl phthalate was more effective against the common malaria mosquito, *Anopheles quadrimaculatus* Say. Another compound, *Indalone*, which had been developed as a fly repellent, was found to be effective against the stable fly, *Stomoxys calcitrans* (L). (Travis & Smith 1950). To take advantage of their specific properties, the three compounds were combined in the proportion of 6 parts of dimethyl phthalate and 2 parts each of Rutgers 612 and *Indalone* (Travis & Jones 1944). Upon the recommendation of the Bureau, dimethyl phthalate, Rutgers 612, and later this mixture, known as 6-2-2, were adopted as standard-issue repellents by the U. S. Army.

Most of the effective compounds were produced originally only in small experimental quantities and are not commercially available. Three that are obtainable are dimethyl carbate (dimethyl ester of *cis*-bicyclo [2.2.1]-5-heptene-2,3-dicarboxylic acid), 2-phenoxyethyl acetate, and 2-phenylcyclohexanol. The last-named material appeared to be of promise (Jones & Travis 1946) and was later adopted by Naval Research workers as the principal ingredient of Repellent 448 (Jachowski & Pijoan 1946). Toxicological tests by the U. S. Food and Drug Administration, however, indicated that this compound and Repellent 448 were unsafe for extended use on the skin (Draize *et al.* 1948), and they were dropped by the Orlando laboratory from further consideration. A compound that was recently found to be more effective than any of the standard repellents against subarctic species of *Aëdes* was propyl *N,N*-diethylsuccinamate (King 1948, Applewhite & Smith 1950). It also appeared to be of promise in a mixture with other repellents.

A list of the more effective repellents tested at Orlando against *Aëdes aegypti* and *Anopheles quadrimaculatus* has been published by Travis *et al.* (1949). A further selection of the most effective compounds that are deemed safe for use on man has been published by Travis & Smith (1951). This contains a list of 14 individual repellents and 12 mixtures. Reports of other studies on repellents for black flies (Travis, *et al.* 1951), sand flies (Travis & Morton 1950), and several species of *Anopheles* (Travis 1947, 1951) have been published. An important paper by Christophers (1947) contains a review of mosquito repellent investigations in England.

The work at the Orlando laboratory on repellents applied to the skin was later enlarged to include an extensive investigation of repellents applied to the clothing for protection against several species of important bloodsucking arthropods, including mosquitoes, ticks, fleas, and chigger mites. Some of the compounds that have given particularly good results

[1] This work was conducted under funds allotted by the Department of Defense to the Bureau of Entomology and Plant Quarantine.

[2] Presented by invitation at the meeting of the American Association of Economic Entomologists at Denver, Colo., Dec. 1950.

for the different purposes are shown below. All were considered to be safe for use on the outer clothing, as a result of tests on rabbits by the U. S. Food and Drug Administration, but some may not pass tests on man now being conducted by the Army Industrial Hygiene laboratory. Species against which they have been tested include the mosquitoes *Aëdes aegypti*, *A. taeniorhynchus*, and *Anopheles quadrimaculatus* (Smith & Burnett 1949, Smith & Cole 1951); the lone star tick *Amblyomma americanum* (L). Smith & Gouck 1946, (Smith & Burnett 1948, Smith *et al.* 1949. Smith & King 1950, Cole & Smith 1949); the cat flea, *Ctenocephalides felis* (Bouché), and the oriental rat flea, *Xenopsylla cheopis* Rothsch. (Smith & Burnett 1948); and the chigger mites, *Trombicula masoni* Ewing and *T. alfreddugesi* (Oud.) (Snyder & Morton 1946a, b and 1947; Cross & Snyder 1948 and 1949). Some of the materials were also tested against subarctic species of *Aëdes* (Applewhite & Smith 1950, Applewhite & Cross 1951), and a few of the tick repellents have been tested, by Granett & French (1950) against the American dog tick, *Dermacentor variabilis* (Say), and by Brennan (1947) against *Dermacentor andersoni* Stiles and *Amblyomma americanum*. The compounds not known to be commercially available are indicated by an asterisk.

REPELLENTS EFFECTIVE AS CLOTHING TREATMENTS

Against mosquitoes:
- Methyl *N,N*-diisopropyladipamate*
- 2-Butyl-2-ethyl-1,3-propanediol
- *N*-Butyl-1,2,3,6-tetrahydrophthalimide*
- *Indalone*
- Undecylenic (hendecenoic) acid
- 2,4-Nonanediol*
- alpha-Butoxy-*N*-cyclohexylacetamide*
- Dimethyl phthalate
- Rutgers 612

Against ticks:
- *N*-Butylacetanilide
- Hexyl mandelate
- *Indalone*
- alpha-Butoxy-*N*-cyclohexylacetamide*
- *N,N*-Dibutylacetoacetamide*
- *N*-Propylacetanilide
- Undecylenic (hendecenoic) acid

Against fleas:
- Undecylenic (hendecenoic)acid
- Benzyl benzoate
- *N*-Butylacetanilide
- *N*-Propylacetanilide
- Hexyl mandelate

Against chiggers:
- Diphenyl carbonate
- Benzil
- *p*-Tolyl benzoate
- Benzyl benzoate
- Dibutyl phthalate
- Dimethyl phthalate

All these materials remained effective for at least 10 days (usually much longer) after the clothing had been treated, and withstood several days' wear of the garments. The usual treatment was at the rate of 2 grams of repellent per square foot of cloth, or approximately 5 per cent of the dry weight. The compounds effective against mosquitoes, ticks, and chiggers have given good results in both laboratory and field tests. Field conditions suitable for testing the flea repellents are seldom to be found, and these materials were therefore evaluated in small pens in which laboratory-reared fleas were released in much larger numbers than ordinarily occur in natural infestations, especially of rat fleas.

Of the mosquito repellents, the first two on the list have remained highly effective for periods up to 149 days of aging and 56 hours of wear. The two standard repellents for use on the skin, dimethyl phthalate and Rutgers 612, have withstood 27 days of aging and 16 hours of wear. 2,4-Nonanediol and dimethyl phthalate were two of the best against *Anopheles quadrimaculatus* in laboratory tests.

Of the tick repellents, *N*-butylacetanilide has been the most consistently effective in numerous field tests against the lone star tick. It is also effective against mosquitoes and fleas, and in fact first came to notice at the Orlando laboratory as a mosquito repellent. It was later tested by Brennan (1947) against *Dermacentor andersoni*, as well as the lone star tick.

The materials listed as effective against chiggers are toxicants rather than repellents as they kill or paralyze the chiggers very quickly. The first three materials are solids and garments treated with them remain highly effective after six or more launderings. These materials have also given good results when incorporated into dusting powders.

Benzyl benzoate and a mixture of equal parts of this compound and dibutyl phthalate were used for protection of troops against scrub typhus, or tsutsugamushi disease, in New Guinea and the Philippines during World War II. Gar-

ments treated with benzyl benzoate remain effective after two, and sometimes after three or four, launderings. Besides these materials, the standard repellents dimethyl phthalate, Rutgers 612, and the 6-2-2 mixture are effective when applied either to skin or clothing, but are not resistant to water.

One of the important findings in connection with repellent research was that materials vary a great deal in their effectiveness against different species of mosquitoes. In general, the duration of effectiveness was much less against *Anopheles* than against species of other genera. Considerable variation was also noticed in the effectiveness of the repellents on different persons, under different weather and atmospheric conditions, and at different times or places with the same species of mosquitoes (Travis 1950).

Recently, attention has been given to the development of an all-purpose repellent or mixture, for clothing impregnations, which would give protection against all four groups of arthropods previously mentioned. Various combinations of the best repellents have been tried, and several of the mixtures have given very promising results, particularly those containing N-butylacetanilide, 2-butyl-2-ethyl-1,3-propanediol, and one of the chigger toxicants (Smith & Cole 1951). More field testing will be required before final recommendations can be made.

INSECTICIDES.—With all the recent developments in the field of insecticides, particularly the chlorinated hydrocarbons it is impossible to give an adequate summary of their status and known uses in a short paper, even when limited to the relatively small field of medically important insects.[3] DDT has had some stiff competition and has been supplanted for use against many insects. Nevertheless, it is still preeminent in residual effectiveness when applied to walls and other surfaces on which insects crawl or rest. This property has made possible the effective reduction of malaria in regions where the low economic status of the population rendered the cost of other methods prohibitive. This property has also been of remarkable value in the control of flies, bedbugs, and cockroaches.

During the last 3 years the problem of increased insect resistance to DDT has entered the picture and threatens to nullify much of the advantage that has been gained. In some sections of the country the entire natural house fly populations have become so resistant that control by residue treatments is no longer possible. At Orlando a laboratory-produced colony of flies has become practically immune to DDT, as the adults live and reproduce normally in a cage completely covered with a layer of DDT. Laboratory studies and field observations have indicated also that flies already resistant to DDT quickly develop an increased resistance to other insecticides, suggesting that the rotation of insecticides will not long provide effective control. The resistance problem is extremely serious, and there is reason to believe that the use of insecticides for fly control will soon be greatly curtailed or supplemented by other methods.

Within the last 2 years increased resistance to DDT has been demonstrated among salt-marsh mosquitoes in Florida (Deonier *et al.* 1950, King 1950) and floodwater *Aëdes* in California (Bohart & Murray 1950). It is thought that resistance in mosquitoes may follow the pattern of house fly resistance, but probably more slowly. In both cases attention must again be given to the development of other methods of control.

In spite of this rather dark picture, DDT has a continuing field of usefulness in medical entomology. One of the outstanding achievements with this material was the spectacular control of human body lice when it was applied to the clothing as a 10 per cent dust. Some other important uses are as a residue in and around buildings for the control of malaria mosquitoes, nonresistant flies, cockroaches, bedbugs, and ants; as a dust for the control of fleas about the grounds, in outbuildings, and in rat runways; as sprays for use against various insects in buildings and living quarters, and for the area control of mosquitoes, sand flies, black flies, house flies, and ticks. DDT has also been incorporated into an emulsifiable formula known as NBIN as a combination treatment for head lice, crab lice, and scabies. Benzocaine is included in the formula as a louse ovicide, and benzyl benzoate as the scabies remedy.

[3] A good recent review of the literature, with a list of more than 100 references, has been published by Andrews & Simmons (1948).

A large number of analogs of DDT have been prepared and a few of them have shown considerable toxicity to some insects. Two that are commercially available are methoxychlor and TDE (dichlorodiphenyldichloroethane). The former has been used extensively as a residue treatment to control house flies and the latter as a mosquito larvicide (Deonier *et al.* 1946). Methoxychlor is less toxic than DDT to vertebrates generally and less likely to be stored in fatty tissue. For these reasons it is one of the few insecticides that has been recommended by our Bureau for use in dairy barns. TDE also holds a favorable toxicological position in comparison with DDT and can be used as a larvicide with less danger to fish or other desirable aquatic animals. It has recently been used with remarkably good results for the control of the Clear Lake gnat in California (Lindquist & Roth 1950). Several bromo-, iodo-, and fluoroanalogs have shown a high degree of toxicity to insects but have not as yet been developed commercially.

Chlordane and benzene hexachloride have been tested extensively against insects affecting man. Both are more toxic than DDT to house flies and cockroaches and have greater vapor toxicity, but their duration of effectiveness as residues is shorter. Lindane, the essentially pure gamma isomer of benzene hexachloride, is also more toxic than DDT to mosquitoes, whereas chlordane is less so to most species. Because the toxicological hazards have not been fully assessed, chlordane is not recommended for residue treatments of the entire wall surface inside dwellings, but may be used effectively for cockroach and ant control by treating only the portions of the buildings where the insects are known to hide or crawl. Technical benzene hexachloride has a musty odor which makes it unpleasant for use in living quarters, but the gamma isomer has much less odor and is marketed in England as a household spray.

Both chlordane and benzene hexachloride have given outstanding results against DDT-resistant house flies, but the effectiveness was short-lived in some localities. Increased resistance to each compound appeared after a season's use in Florida, and rapid development of resistance to benzene hexachloride has been reported in California (March & Metcalf 1949 and 1950) and Egypt (Gahan & Weir 1950). The latter insecticide has also given outstanding results in controlling salt-marsh mosquitoes in areas where DDT resistance has appeared (Deonier & Gilbert 1950, King 1950, and Deonier *et al.* 1950). Both materials appeared promising in preliminary experiments on the control of salt-marsh sand flies of the genus *Culicoides* (Goulding 1950).

Toxaphene is the fourth member of what has been called the "Big Four," but has shown less promise than the others for use against the species affecting man. It has given fairly good results in dairy barns against DDT-resistant flies (Gilbert *et al.* 1950, King 1950) and as a larvicide against DDT-resistant salt-marsh mosquitoes. As a mosquito larvicide, however, it must be used with caution, as it is much more toxic to fish than the other materials under discussion.

In the area control of the lone star and American dog ticks, DDT, chlordane, and toxaphene are all about equally effective (McDuffie *et al.* 1950, King 1948, Gouck & Fluno 1950), but against chiggers DDT is considerably less effective than the other two. Benzene hexachloride has also shown good immediate effects against both ticks and chiggers, but the residual effects are less favorable.

Toxaphene applied to clothing either as a dust or in solution is superior to DDT as a louse toxicant. Chlordane and benzene hexachloride are also very effective (Eddy & Bushland 1948), but none of these three has yet been tested sufficiently to determine its toxicity to man if used for this purpose.

Several new chlorinated hydrocarbon insecticides of interest are beginning to appear on the market after several years of developmental and experimental work. Of these, special mention may be made of dieldrin, aldrin, and heptachlor. Dieldrin has proved to be the most toxic of any of this class of insecticides to mosquitoes, flies, and cockroaches, and is also very promising as a residual treatment. Aldrin and heptachlor are generally less toxic than dieldrin, but compare favorably with some of the other materials against different species. Heptachlor is especially effective as a dust for flea control. Although dieldrin has been used experimentally without apparent adverse results for fly control in dairy barns and

outdoors in towns, more work on the toxicology of these compounds is needed to determine how extensively they may be used with safety inside buildings.

Several organic phosphates, including parathion, have recently been developed as insecticides and have shown a high degree of toxicity to many species. These compounds, unfortunately, are also highly toxic to warm-blooded animals, and at present are not recommended for use in the control of insects in dwellings or barns. Parathion is highly effective against ticks and chiggers on the ground and against most mosquito larvae, and it is possible that it could, with proper precautions, be used to some extent for their control when other materials fail.

Pyrethrum, one of the oldest of the insecticides, should not be omitted in a review of this kind, as it still has important uses, especially in household sprays and aerosols. It is almost unique in rapidity of action, and it is practically harmless to mammals. Several compounds, such as sesame oil, piperonyl butoxide and piperonyl cyclonene, have been discovered to have a synergistic or activating effect on pyrethrins, which greatly increases their potency against house flies, body lice, and some other species.

A particularly important development in the insecticide field in recent years is the synthesis of several compounds closely related to the active principles of pyrethrum (Schechter *et al.* 1949). Allethrin, a completely synthetic allyl homolog of cinerin I, is now being produced commercially and has been evaluated for use against a wide variety of insects. This work has been reviewed by Bishopp (1950) and by McNamee *et al.* (1950). Allethrin has proved more effective than pyrethrum extract against some species and less so against others. It appears to be equally nontoxic to warm-blooded animals and may be more stable than pyrethrum. It will undoubtedly be a valuable supplement to pyrethrum for some uses and replace it entirely for others.

LITERATURE CITED

Andrews, Justin M., and S. W. Simmons. 1948. Developments in the use of the newer inorganic insecticides of public health importance. Amer. Jour. Pub. Hlth. **38**: 613–31.

Applewhite, K. H., and H. F. Cross. 1951. Further studies of repellents in Alaska. JOUR. ECON. ENT. (In press.)

Applewhite, K. H., and Carroll N. Smith. 1950. Field tests with mosquito and sand fly repellents in Alaska. JOUR. ECON. ENT. **43**(3): 353–7.

Bishopp, F. C. 1950. Allethrin. Agr. Chem. **5**: 22.

Bohart, R. M., and W. D. Murray. 1950. DDT resistance in *Aëdes nigromaculis* larvae. Proc. 18th Ann. Conf. Calif. Mosquito Control Assoc., pp. 20–21.

Brennan, J. M. 1947. Preliminary report on some organic materials as tick repellents and toxic agents. U. S. Pub. Health Serv. Rpts. **62**: 1162–5.

Christophers, S. Richard. 1947. Mosquito repellents. Jour. Hygiene **45**(2): 176–231.

Cole, Moses M., and Carroll N. Smith. 1949. Tick repellent investigations at Bull's Island, S. C. 1948. JOUR. ECON. ENT. **42**(6): 880–3.

Cross, H. F., and F. M. Snyder. 1948. Field tests of uniforms impregnated with mite toxicants: I, Protection studies. JOUR. ECON. ENT. **41**(6): 936–40.

Cross, H. F., and F. M. Snyder. 1949. Chigger control—washing and aging tests of a selected group of compounds effective as clothing treatments against chiggers. Soap and Sanit. Chem. **25**(2): 135, 137, 139, 141, 143.

Deonier, C. C., and I. H. Gilbert. 1950. Resistance of salt-marsh mosquitoes to DDT and other insecticides. Mosquito News **10**(3): 138–43.

Deonier, C. C., T. L. Cain, Jr., and W. C. McDuffie. 1950. Aerial spray tests on adult salt-marsh mosquitoes resistant to DDT. JOUR. ECON. ENT. **43**(4): 506–10.

Deonier, C. C., H. A. Jones, H. L. Haller *et al.* 1946. Mosquito larvicide tests. Soap and Sanit. Chem. **22**(11): 118, 119, 139.

Draize, John H., Elsie Alvarez, Marie F. Whitesell, Geoffrey Woodard, E. Conway Hagan, and Arthur A. Nelson. 1948. Toxicological investigations of compounds proposed for use as insect repellents. A. Local and systemic effects following topical skin application; B. Acute oral toxicity; C. Pathological examination. Jour. Pharmacol. and Expt. Ther. **93**: 26–39.

Eddy, G. W., and R. C. Bushland. 1948. Compounds more toxic than DDT against body lice. JOUR. ECON. ENT. **41**(3): 369–73.

Gahan, James B., and John M. Wier. 1950. Houseflies resistant to benzene hexachloride. Science **111**(2894): 651–2.

Gilbert, I. H., H. G. Wilson, and J. M. Coarsey. 1950. Control of house flies in barns with different insecticides. U. S. Bur. Ent. and Plant Quar. E-795,

Gouck, Harry K., and John A. Fluno. 1950. Field tests on control of American dog ticks in Massachusetts. JOUR. ECON. ENT. **43**(5): 698–701.

Goulding, **Robert L., Jr.** 1950. A report on the investigations conducted by the Cooperative Sand Fly Research Unit in South Florida. Rpt. 21st Ann. Meeting Fla. Anti-Mosquito Assoc., pp. 102–12.

Granett, **Philip,** and Carl F. French. 1950. Field tests of clothing treated to repel American dog ticks. JOUR. ECON. ENT. **43**(1): 41–4.

Granett, **Philip,** and Harry L. Haynes. 1945. Insect repellent properties of 2-ethylhexanediol-1,3. JOUR. ECON. ENT. **38**: 671.

Jachowski, **L. A., Jr.,** and M. Pijoan. 1946. Two new effective insect repellents, NMRI-201 and NMRI-448. Science **104**: 266–9.

Jones, **Howard A.,** and Bernard V. Travis. 1946. Insect repellent compositions. U. S. Patent 2,396,013, issued Mar. 5.

King, **W. V.** 1948. Some results of recent work on the newer insecticides. Amer. Jour. Trop. Med. **28**(3): 487–97.

King, **W. V.** 1950. DDT-resistant house flies and mosquitoes. JOUR. ECON. ENT. **43**(4): 527–32.

Lindquist, **A. W.,** and A. R. Roth. 1950. Effect of dichlorodiphenyl dichloroethane on larvae of the Clear Lake gnat in California. JOUR. ECON. ENT. **43**(3): 328–32.

March, **Ralph B.,** and Robert L. Metcalf. 1949. Development of resistance to organic insecticides other than DDT by houseflies. JOUR. ECON. ENT. **42**: 990.

March, **Ralph B.,** and Robert L. Metcalf. 1950. Insecticide-resistant flies. Soap and Sanit. Chem. **26**: 121.

McDuffie, **W. C.,** G. W. Eddy, J. C. Clark, and C. N. Husman. 1950. Field studies with insecticides to control the lone star tick in Texas. JOUR. ECON. ENT. **43**(4): 520–7.

McNamee, **R. W.,** J. B. Moore, Donald Starr, Kenneth Nash, Howard A. Jones, and H. L. Haller. 1950. Symposium on allethrin. Soap and Sanit. Chem. Proc. Chem. Specialties Mfrs. Assoc. pp. 57–67.

Schechter, **M. S.,** N. Green, and F. B. LaForge. 1949. The synthesis of cyclopentenolones of the type of cinerolone. Jour. Amer. Chem. Soc. **71**: 1577.

Smith, **C. N.,** and D. Burnett, Jr. 1948. Laboratory evaluation of repellents and toxicants as clothing treatments for personal protection from fleas and ticks. Amer. Jour. Trop. Med. **28**(4): 599–607.

Smith, **C. N.,** and D. Burnett, Jr. 1949. Effectiveness of repellents applied to clothing for protection against salt-marsh mosquitoes. JOUR. ECON. ENT. **42**(3): 439–44.

Smith, **C. N.,** and M. M. Cole. 1951. Mosquito repellents for application to clothing. Jour. Natl. Malaria Soc. (In press.)

Smith, **Carroll N.,** M. M. Cole, Elmer A. Jones, and J. C. Clark. 1949. Investigations of tick repellents at Camp Bullis, Texas, 1948. JOUR. ECON. ENT. **42**(5): 716–20.

Smith, **Carroll N.,** and Harry K. Gouck. 1946. Observations on tick repellents. JOUR. ECON. ENT. **39**(3): 374–8.

Smith, **Carroll N.,** and W. V. King. 1950. Field studies of tick repellents. Amer. Jour. Trop. Med. **30**(1): 97–102.

Snyder, **F. M.,** and F. A. Morton. 1946a. Chigger repellents—Benzyl benzoate, dimethyl phthalate, and dibutyl phthalate for impregnation of clothing to prevent chigger (mite) attachments. Soap and Sanit. Chem. **22**(11): 133, 135.

Snyder, **F. M.,** and F. A. Morton. 1946b. Materials as effective as benzyl benzoate for impregnating clothing against chiggers. (Scientific Note.) JOUR. ECON. ENT. **39**(3): 385–6.

Snyder, **F. M.,** and F. A. Morton. 1947. Benzyl benzoate-dibutyl phthalate mixture for impregnation of clothing. JOUR. ECON. ENT. **40**(4): 586–7.

Travis, **B. V.** 1947. Relative effectiveness of various repellents against *Anopheles farauti* Laveran. Jour. Natl. Malaria Soc. **6**(3): 180–3.

Travis, **B. V.** 1950. Known factors causing variation in results of insect repellent tests. Mosquito News **10**(3): 126–32.

Travis, **B. V.** 1951. Effectiveness of repellents against several species of *Anopheles* mosquitoes. Jour. Natl. Malaria Soc. (In press.)

Travis, **Bernard V.,** and Howard A. Jones. 1944. Insect repellent composition. U. S. Patent No. 2,356,801, issued August 29.

Travis, **B. V.,** and F. A. Morton. 1950. Insect repellents and nets for use against sand flies. N. J. Mosq. Extermin. Assoc. Proc. **37**: 154–6.

Travis, **B. V.,** F. A. Morton, Howard A. Jones, and J. H. Robinson. 1949. The more effective mosquito repellents tested at the Orlando, Fla., laboratory, 1942–47. JOUR. ECON. ENT. **42**(4): 686–94.

Travis, **B. V.,** and A. L. Smith. 1950. Tests with repellents against the stable fly. Amer. Vet. Med. Assoc. Jour. (In press.)

Travis, **B. V.,** A. L. Smith, and A. H. Madden. 1951. Effectiveness of insect repellents against black flies. JOUR. ECON. ENT. **44**(3): (In press.)

Travis, **B. V.,** and Carroll N. Smith. 1951. Mosquito repellents selected for use on man. JOUR. ECON. ENT. (In press.)

Effect of Parathion on Parasites of *Coccus hesperidum*[1]

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Parathion sprays applied to citrus trees in California for control of certain scale insects and citrus thrips or both, at times cause an increase in populations of the soft (brown) scale, *Coccus hesperidum* L. This scale is usually considered of no economic significance on citrus, but if its natural enemies are suppressed by the action of parathion it may become a serious pest. Heavy infestations of soft scale cause a reduction in fruit set, and when sooty-mold fungus develops on the excreted honeydew, fruit grade is reduced.

Soft scale is of general occurrence in citrus-growing areas. Infestations are occasionally encountered in citrus orchards but they are more commonly found on ornamental plantings in dooryards, greenhouses, or other protected locations. Normal infestations on citrus occur most often near the ground level, in colonies, and attended by ants. Parasitization in these colonies is represented in coastal and intermediate areas of the citrus belt by certain encyrtids, namely, *Microterys flavus* (Howard), which attacks half-grown to nearly mature scale, and *Metaphycus luteolus* (Timb.), which attacks young scale (0.8 mm. in length) to nearly mature scale; and by the aphelinid *Coccophagus scutellaris* (Dal.), which attacks half-grown to nearly mature scale. In interior areas *Microterys flavus* is not found, and *C. lycimnia* (Walk.), a species very similar to *C. scutellaris* in appearance and habits, is sometimes taken. *Metaphycus stanleyi* Compere is of rare occurrence. *M. flavus* is occasionally effective in reducing soft-scale infestations in coastal areas, but there is little evidence that either of the *Coccophagus* species is capable of accomplishing economic control without the assistance of *M. luteolus*. The *Coccophagus* species are capable of rapid oviposition and for this reason do not appear to be greatly impeded by the activity of ants. *M. luteolus*, on the other hand, is severely handicapped by ant activity and gains ascendance over an ant-attended soft-scale colony only after a considerable period.

Metaphycus luteolus was reported by Timberlake (1913) to be the most generally effective natural enemy of soft scale. The effectiveness of this parasite is confirmed by the present study. After the soft-scale build-up following parathion treatment, *M. luteolus*, although never found in the infested orchards until after complete weathering of the residue and parasite re-establishment, was the single species responsible for the rapid biological control that took place.

M. luteolus is most effective as a parasite of soft scale, but it is not uncommonly responsible for satisfactory natural control of the citricola scale, *Coccus pseudomagnoliarum* (Kuw.), in southern California (DeBach 1949). It also attacks immature black scale, *Saissetia oleae* (Bern.), to a limited extent, and at times has been shown to reduce infestations of black scale below the level of economic importance (Swain & Duggan 1928).

Under summer weather conditions *Metaphycus luteolus* develops in approximately 18 days from egg to adult; it thus completes two generations to one of its soft-scale host. This parasite oviposits in young to nearly mature scale, and in laboratory cultures it kills a large proportion of the scales that are below ovipositional size by attempted oviposition or by host feeding similar to that shown by Flanders (1942) for the closely allied black scale parasite *M. helvolus* (Comp.).

The natural control of parathion-induced infestations of soft scale by *Metaphycus luteolus* has been followed in field studies through all seasons of the year. There have been no indications that the activity of the parasite is seriously retarded by the seasonal temperatures found in the southern section of the state, so far as its soft-scale host is involved. Its abundance on citricola scale is correlated with the abundance of stages of scale suitable for parasite oviposition on this single-brooded host.

In as little as 6 weeks to 2 months after parathion application to citrus trees soft scale may become evident, particularly around the tree skirts, in a more or less

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normal distribution, in contrast to the usual ant-attended colonial distribution. If the humidity is low, glistening droplets of honeydew are evident on the leaves. If the humidity is high, sooty-mold fungus rapidly develops on the honeydew. During the period of lethal parathion residue, *Metaphycus luteolus* is completely eliminated from the orchard. Live *Coccophagus scutellaris* can often be found at this time. The developmental period of the *Coccophagus* species is extremely variable, in keeping with the hyperparasitic conditions necessary for male production; therefore, unemerged adults can often be found a long time after parathion application as the result of eggs laid prior to treatment.

Normally, within 2 to 4 months after parathion treatment of the trees, *Metaphycus luteolus* becomes re-established in soft-scale-infested orchards, and 1 to 3 months later, the length of time depending on climatic conditions, the scale is brought under biological control. Successive periods of soft-scale abundance of lesser intensity may occur even a year or more later in some cases. This resurgence of the pest apparently follows a more or less natural condition of oscillation of host and parasite population density occasioned by the nearly complete elimination of scale of a size suitable for oviposition, and the consequent migration or death of the parasite. Re-establishment of the parasite and a state of permanent host-parasite balance is achieved rapidly in such cases, but retreatment with parathion before such balance is achieved could presumably lead to disastrous scale infestations.

Laboratory tests and laboratory and field bioassays of toxic-residue retention have shown some interesting interrelationships between the parasites, the soft scale, and parathion. *Metaphycus luteolus* is not extraordinarily susceptible to parathion. Comparative tests indicate that this species shows approximately the same degree of susceptibility to parathion residues as does the black scale parasite *M. helvolus*. Susceptibility to parathion is considerably less with *M. luteolus* than with the more delicate California red scale parasites such as *Aphytis chrysomphali* (Mercet). Despite the susceptibility of the parasites of black scale and California red scale to this material, parathion-induced increases in populations of these scale insects have not as yet been recorded. The difference lies in the fact that few or none of the soft (brown) scales are killed by the action of parathion, whereas scale hosts of the other parasite species are susceptible to this material.

Measurements of the toxicity of field-weathered parathion residues on treated citrus foliage were obtained by laboratory bioassays of excised leaves, using both *Metaphycus luteolus* and *Aphytis chrysomphali* as test insects. Residues of applications ranging from 2.5 pounds to 15 pounds of actual parathion per acre were tested at intervals after treatment. Disappearance of effective parasite-killing residues ranged from 50 days to more than 105 days, the length of time depending largely on dosages applied. Even the more temporary residues were at times capable of stimulating serious infestations of the soft scale where initial populations had been moderately heavy.

No unusual relationships appear to be associated with parathion residues with respect to effects of the insecticide on the parasite through its hosts. In one experiment, rooted Lisbon lemon cuttings were sprayed in the laboratory with 0.1 per cent actual parathion and infested the following day with soft-scale crawlers. When held under greenhouse conditions, no difference in rate of development could be observed between these scales and scales reared under comparable conditions but on untreated plants. Fifty days later, when treatment residues were almost entirely dissipated, exposure of treated and untreated plants, with their infestations of half- to two-thirds-grown scale reared on treated and untreated foliage, resulted in no significant differences in parasitization or emergence.

One peculiar feature in the re-establishment of *Metaphycus luteolus* after parathion treatment is that the scale infestation is brought under natural balance by the parasites more quickly in the upper portions of an infested tree than on the leaves and twigs near the ground level. This may be associated with the longer retention of parathion in the soil, particularly under the drip of the tree fringe, as demonstrated in the following test.

Three and one-half months after treatment 1-quart soil samples were taken from the top inch of soil under citrus

tree skirts in a grove receiving the very high dosage of 15 pounds of actual parathion per acre. Each soil sample was placed in an open-mouthed 2-quart mason jar, and caged *Aphytis chrysomphali* were so placed in the jar as to avoid direct contact with the soil. In two separately run soil tests the insects were all killed within a 24-hour period, whereas in two tests with similarly caged insects placed over untreated soil, mortalities suffered by the parasites were less than 10 per cent in each jar.

The degree of seriousness attained by parathion-instigated infestations of *Coccus hesperidum* appears to be as greatly dependent upon the availability of parasite reservoirs as upon the retention of toxic residues by trees and soil, since periods ranging up to 2 or 3 months may elapse after breakdown of residues before field examination reveals the presence of the parasite.

Availability of parasites for re-establishment in a parathion-treated orchard is associated with reservoirs of both soft scale and citricola scale in surrounding untreated areas. Shortened periods between loss of toxic residue and re-establishment of parasites have been observed where parasitization of citricola scale in surrounding areas is heavy. However, the variable rate of development of *Metaphycus luteolus* at different seasons has made data on this question difficult to obtain. In certain instances it has appeared that reservoirs may even be retained within a treated grove on very small trees harboring ant-attended soft-scale colonies; this suggests that parathion residues are more quickly dissipated from such small, lightly foliated trees than from larger ones.

Parathion may be applied to citrus at nearly any time of year; consequently, large contiguous areas are rarely treated at any one time. This feature of parathion application has, so far, favored ready re-establishment of parasites after disappearance of toxic residues.

Since, as the present studies have shown, natural re-establishment of parasites is sometimes delayed, and since biological control occurs shortly after parasites are re-established, it may readily be concluded that artificial colonization of the parasites immediately after the disappearance of the toxic residue would aid in avoiding severe damage. Inexpensive recolonization has been accomplished by transfer of parasitized material from one grove to another, as well as by liberation of insectary-reared parasites. No field studies of designed liberations of this type have been completed, but in two greenhouse tests in which parathion sprays have been used on citrus, and in which there has been evidence of increased infestations of soft scale, moderate periodic liberations of *Metaphycus luteolus* have prevented serious injury and have made possible the early attainment of a favorable biological balance between the parasite and its host.

SUMMARY.—Serious increases in populations of the soft (brown) scale, *Coccus hesperidum* L., have been associated with the application of parathion to citrus trees. Soft-scale infestations, with their parasite complements, in parathion-treated groves and in untreated groves are compared.

Characteristic features of the life history of *Metaphycus luteolus* (Timb.), the most effective parasite of *Coccus hesperidum*, are reviewed. Parathion-treated groves have been found to be lethal to adults of *M. luteolus* for periods ranging from 6 weeks to 3 months or more, the length of the period depending on the dosages used. Re-establishment of *M. luteolus* in groves after parathion residues are dissipated results in rapid biological control.

In comparison with other parasitic Hymenoptera tested, *Metaphycus luteolus* is not extraordinarily susceptible to parathion. Soft scale reared on parathion-treated citrus was as susceptible to parasitization by *M. luteolus* as scale reared on untreated citrus. The combination of parasite suppression and low host toxicity by parathion causes increased abundance of soft scale. Prolonged retention of parathion in the soil after spray treatment was demonstrated.

Parasite reservoirs are discussed in connection with parathion treatment, since delays in re-establishment of the parasites are correlated with the degree of seriousness of parathion-induced soft-scale population upsets.

Artificial colonization of *Metaphycus luteolus* in greenhouses after parathion treatment has prevented serious increases in soft-scale infestations.

LITERATURE CITED

DeBach, Paul. 1949. Citricola scale parasites. California Citrog. 34(4): 168.

Flanders, Stanley E. 1942. *Metaphycus helvolus*, an encyrtid parasite of the black scale. JOUR. ECON. ENT. 35: 690–98.

Swain, A. F., and Charles E. Duggan. 1928. Significance of mid-season units counts on resistant black scale. JOUR. ECON. ENT. 21: 532–42.

Timberlake, P. H. 1913. Preliminary report on the parasites of *Coccus hesperidum* in California. JOUR. ECON. ENT. 6: 293–303.

Results of Tests for Greenbug Control[1]

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A widespread infestation of the greenbug, *Toxaptera graminum* (Rond.), on small grains in Texas during 1950 provided an excellent opportunity for evaluating insecticides for control of this pest both in the laboratory and in the field. The laboratory work reported in this paper was done at the Entomological Research Laboratory at College Station, Texas. Field tests were conducted in Brazos, Travis and Baylor counties.

LABORATORY TESTS.—Single barley plants grown in 2-inch pots were infested with greenbugs. These infested plants were treated with benzene hexachloride dust, benzene hexachloride spray, parathion dust or tetraethyl pyrophosphate spray in order to determine the toxicity of these materials to greenbugs.

Applications of dusts were made by placing each infested plant in an open top-dusting tower, 12 inches in diameter, and introducing a known amount of dust later calculated to the acre basis. The dusts used were: 3 per cent gamma benzene hexachloride and 1 per cent parathion. The diluent used in these dust mixtures was a fuller's earth type clay. The sprays were applied to the infested potted plants with the apparatus described by Gaines & Dean (1950). The electrically driven machine was adjusted so that the plants would pass under a fixed nozzle at the rate of 4 miles per hour. The amount of spray each plant received was approximately the same as would have been received from a tractor sprayer applying 6 gallons per acre. This rate was maintained throughout the tests and different dosages were obtained by varying the concentrations of the sprays.

Toxicity data were obtained by counting the greenbugs on each plant before treatment and 24 hours after treatment. During this treatment period the plants were exposed to outside temperatures ranging from 48° F. to 70° F. each day. The dosage-mortality relationships for the various materials are shown in figure 1. The dosage required to give 50 per cent mortality, 90 per cent mortality and the slope of the line are shown in table 1.

Parathion and tetraethyl pyrophosphate sprays were more toxic to greenbugs than benzene hexachloride dust or spray.

FIELD TESTS.—The first field test, as shown in table 2, was made to determine the comparative effectiveness of benzene hexachloride and tetraethyl pyrophosphate sprays for control of greenbugs on oats near Allen farm in Brazos county. A randomized block plat arrangement was used and each treatment was replicated 4 times. Plats were 40 by 54 ft. or approximately one-twentieth acre in size. Infestation records were made by cutting the oats at ground level from 1 foot of drill at 5 different locations in the plat. All the oats cut from each plat was placed in a paper bag marked with the plat letter and block number and carried to the laboratory. There each sample was placed in a battery jar of saturated salt solution and soaked for 15 minutes to remove the aphids from the plants. The plants were then carefully removed from the salt solution and the solution was filtered through a fine plastic screen. Aphids on the screen were then counted with the aid of a large reading glass. Subsequent records were made by cutting the oats from 1 foot of drill at each of five locations adjacent to the five original subsamples. This was done in order to reduce the variation due to location within the plat. Percentages of greenbugs surviving treatment were trans-

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Table 1.—Dosage-mortality relationship of the materials indicated for the control of greenbugs 24 hours after application.

Treatment	Pounds of Active Ingredient per Acre Required to Give Mortality		Slope of Lime
	50 Per Cent	90 Per Cent	
γ Benzene Hexachloride Dust	.045	5.353	.617
γ Benzene Hexachloride Spray	.041	.198	1.903
Parathion Dust	.015	.060	2.182
Tetraethyl Pyrophosphate Spray	.0041	.126	.862

formed to angles for a more discerning analysis of variance. Sprays were applied at the rate of approximately 6 gallons per acre at 40 pounds' pressure. The sprays were applied late in the afternoon at a temperature of 70° F. and were washed off within 8 hours. Temperature range for the duration of the experiment was 50 to 70° F.

Tetraethyl pyrophosphate at both 0.32 and 0.52 pound per acre gave significantly better control than gamma benzene hexachloride at 0.31 pound per acre. There was no difference in effectiveness between the two dosages of tetraethyl pyrophosphate.

Table 2.—Per cent of greenbugs alive 48 hours after treatment in first field test. Allenfarm, Texas.

Treatment	Pounds Active Ingredient per Acre	Per Cent Alive	Angles
Check		61.2	51.8
γ Benzene Hexachloride	.31	20.5	26.1
Tetraethyl Pyrophosphate	.32	6.2	14.4
Tetraethyl Pyrophosphate	.52	5.9	13.9
Min. diff. reg. for sig.		16.7	11.1

The second field test, as shown in table 3, compared the effectiveness of gamma benzene hexachloride at 0.44 pound per acre applied as a dust and at 0.38 pound per acre applied as a spray, parathion dust at 0.11 pound per acre and tetraethyl pyrophosphate spray at 0.35 pound per acre for control of greenbugs. The infested crop in this case was a field of oats near Pflugerville in Travis county. The experimental design and plat size were similar to the first field test and infestation records were made in the same manner. The dusts were applied early in the morning when the temperature was 32–38° F. in a wind of 4 to 8 miles per hour. The sprays were applied later the same morning when the temperature

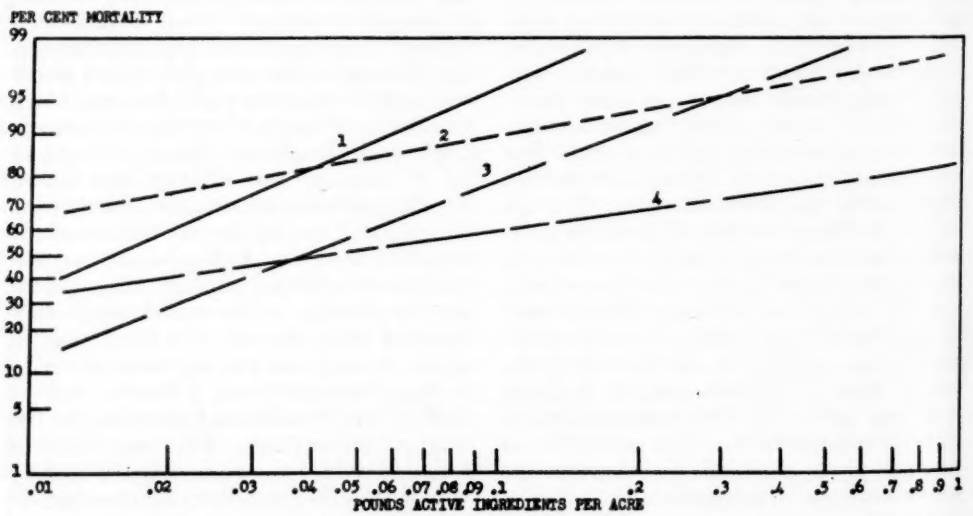

FIG. 1—Dosage-mortality curves for the toxicity of the following insecticides to greenbugs: (1) parathion dust, (2) tetraethyl pyrophosphate spray, (3) gamma benzene hexachloride spray and (4) gamma benzene hexachloride dust.

Table 3.—Percentage of greenbugs alive 48 hours after treatment in second field test. Pflugerville, Texas.

Treatment	Pounds Active Ingredient per Acre	Per Cent Alive
Check		263.4
γ Benzene Hexachloride Dust	.44	64.4
γ Benzene Hexachloride Spray	.38	48.4
Parathion Dust	.11	34.7
Tetraethyl Pyrophosphate Spray	.35	6.9
Min. diff. reg. for sig.		60.8

Table 4.—Percentage of greenbugs alive 48 hours and 7 days after treatment in third field test, Seymour, Texas.

Treatment	Pounds Active Ingredient per Acre	Per Cent Alive	
		48 Hrs.	7 Days
Check		111.0	168.4
γ Benzene Hexachloride	.28	41.5	38.3
Parathion	.19	26.6	17.8
Tetraethyl Pyrophosphate	.27	13.8	23.9
Tetraethyl Pyrophosphate	.52	6.3	19.5
Tetraethyl Pyrophosphate[1]	.26	43.0	69.9
Min. diff. reg. for sig.		24.4	38.1

[1] Sprayed 24 hours later at lower temperature.

was 53 to 66° F. and the wind velocity 15 to 20 miles per hour. Statistical analysis of the percentages of greenbugs surviving did not indicate that the differences between insecticidal treatments were significant. All treatments were significantly better than the check. Transformation of percentages to angles was not practical in the second and third field tests because of the population increases recorded on the check plats.

The third field test, shown in table 4, was located in a field of wheat near Seymour in Baylor county. The purpose of this experiment was to compare the effectiveness of four spray formulations, tetraethyl pyrophosphate at 0.27 and 0.52 pound per acre, gamma benzene hexachloride at 0.28 pound per acre and parathion at 0.19 pound per acre, for greenbug control. An additional treatment of tetraethyl pyrophosphate at 0.26 pound per acre was applied 24 hours later under different weather conditions in order to discover what effect the difference in conditions would have on the amount of control obtained. The plat size, experimental design and procedure were the same as those of the other field tests. The first four treatments were applied about noon when the temperature was 56 to 59° F. and the wind velocity 27 to 31 miles per hour. The delayed application was made about the same time the following day when the temperature was 45° F. following a light freeze and the wind velocity was 13 to 14 miles per hour. Most of the greenbugs were up on the leaves of the plants during the treatments applied the first day but on the second day when the delayed treatment was applied a large percentage of them were in the mats of dead leaves at the base of the plants. Parathion and the two tetraethyl pyrophosphate treatments which were applied the first day gave significantly better control than the tetraethyl pyrophosphate treatment which was applied the second day at a lower temperature. The higher dosage of tetraethyl pyrophosphate was not significantly better than the lower dosage which was applied at the same time. Forty-eight hour and 7 day records indicated that parathion had greater residual toxicity than tetraethyl pyrophosphate. Observations indicated that tetraethyl pyrophosphate killed fewer ladybird beetles than parathion.

SUMMARY.—Laboratory tests were conducted to test the toxicity of parathion dust, tetraethyl pyrophosphate spray, benzene hexachloride dust and benzene hexachloride spray to greenbugs. Parathion and tetraethyl pyrophosphate were more toxic to this insect than benzene hexachloride.

Three replicated field tests were conducted which included treatments with parathion as a dust and as a spray, benzene hexachloride as a dust and as a spray and tetraethyl pyrophosphate spray at two dosage levels. The effects of weather conditions on the effectiveness of insecticidal applications were noted. Results of these field tests are summarized in table 5. The percentages of control were calculated by Abbott's formula.

The materials did not give enough control of greenbugs to be considered a

Table 5.—Summary of greenbug field tests showing percentage control following treatments indicated.

Treatment	Test 1		Test 2		Test 3		
	Dosage[1]	Per Cent Control 48 Hours After Treatment	Dosage	Per Cent Control 48 Hours After Treatment	Dosage	Per Cent Control Hours After Treatment 48	168
γ Benzene Hexachloride Spray	.31	66.6	.38	81.6	.28	62.6	77.3
γ Benzene Hexachloride Dust			.44	75.6			
Parathion Spray					.19	76.0	89.4
Parathion Dust			.11	86.8			
Tetraethyl Pyrophosphate Spray	.32	89.8	.35	97.4	.27	87.6	85.8
	.52	90.4			.52	94.4	88.4
Tetraethyl Pyrophosphate Spray[2]					.26	61.3	58.5

[1] Pounds active ingredients per acre.
[2] Spray applied when temperature was lower than when other applications were made in same experiment.

"knockout." Parathion and tetraethyl pyrophosphate probably did give sufficient control to enable predators and parasites with favorable conditions to restore the natural balance and prevent another damaging increase of the pest. One field test indicated that parathion had greater residual toxicity than tetraethyl pyrophosphate but observations indicated that tetraethyl pyrophosphate was less toxic to ladybird beetles, important predators of greenbugs, than parathion. The degree of control obtained with insecticidal applications seemed to depend to a large extent on the location of the aphids on the plants when the material was applied. This was especially true when there was a mat of dead leaves at the base of the plants to shelter them. Low temperature seemed to be the most important factor in causing these insects to seek shelter. Sprays were much more practical than dusts for greenbug control because they could be applied effectively when the wind was relatively high.

Literature Cited

Gaines, J. C. and H. A. Dean. 1950. Effect of climatic factors on the toxicity of certain insecticides. Jour. Econ. Ent. **43**: 602.

The Seasonal Behavior of Meadow Spittlebug and Its Relation to a Control Method

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The control of nymphs of the meadow spittlebug, *Philaenus leucophthalmus* (L.), by springtime applications of insecticides has some undesirable features that under some conditions prevent the legume grower from applying measures to reduce the damage done by these insects. Forage crop legumes grown for silage and for dehydration into meal are often cut early so that the harvest date comes too soon after the most timely date for effective applications of insecticides. Under any conditions in which the application of insecticides is unacceptable because of the residue hazard, present control methods should not be applied.

Late April and early May are usually busy times for the general farmer and weather conditions often limit the use of ground spraying or dusting equipment in legume fields at that time. With these facts in mind the author presents the following biological observations as being of interest to those concerned with alternate methods of control of the meadow spittlebug.

The spittlebug apparently does not lay its eggs indiscriminately in fields of forage legume crops of different ages. Observations by the writer have revealed that

in northern Ohio the insect usually does not appear in economically important numbers in second and third year meadows.[1] The important damage is usually done in the first year fields. This indicates that the bulk of the eggs must be deposited in the new seedings.

To obtain data on the comparative populations in the first, second, and third year fields, sweep samples were taken from such fields on June 12 when a large percentage of the adult insects had emerged from the spittle masses and migration from the field had not yet started. In this case, the plots sampled were a portion of a field rotation experiment and were located side by side in blocks so that during the previous year the adults would have had an opportunity to lay eggs throughout the block uniformly. The adult populations as measured by the sweeps should be indicative of the relative number of eggs placed there the year before. Adult spittlebugs per sweep of a 15 inch net for the three types of meadow were: first year, 18.1, second year, 2.9, and third year, 0.9. This indicated an overwhelming tendency for the populations to occur in the first year meadow.

Mundinger (1946) states that on grass *Philaenus leucophthalmus* commonly places the egg mass in the axil between leaf and stem and cements the leaf over it. The tendency to lay eggs in crevices between plant portions makes wheat and oat stubble an ideal egg laying medium. The author has observed that eggs are most readily found on grain stubble and only occasionally on legume stubble and green plant parts. The eggs are inserted between the dead leaf sheath and the stem. If the grain stubble serves as a more attractive oviposition site, then the first year meadows, seeded to grain the previous year, would be most likely to receive the majority of the eggs.

Reduction of the succeeding year's nymphs by control of the adults has not presented a promising approach to the control problem because of the rapid reinfestation of treated fields. Wilson (1949) reported little residual effect of DDT upon adults four weeks after treatment applied on July 12. Pielou (1950) showed immediate reductions of adults by DDT applications in June and July, but in nearly every case reinfestation occurred within a few days so that the check and treated populations soon equalized. It must be remembered, however, that such applications have been made to seed fields and not to the newly seeded meadows which will receive the major infestation the following year. During June and July, the new meadow is covered with a grain crop which is not removed until July and sometimes early August. Except for transient hordes of newly emerged adults in June, migrating away from the newly cut first year fields, the grain fields have few adult insects present until the new legume seeding starts to produce a fairly abundant foliage. Figure 1 shows typical adult populations in a first year meadow and in a new seeding. During late July and August the adults will be found in largest numbers in meadows where the vegetation is flourishing. The data in the figure were taken from a field left for a seed crop where there is a natural decline of green succulent foliage as the season progresses. Plants in the new seedings recover from the grain harvest sometime during August, depending upon whether or not the grain stubble is clipped and removed. As the foliage becomes more luxuriant, the adult numbers gradually increase until about the first of September, when there is a tremendous increase suggesting that large numbers of adults are migrating into the newly seeded fields.

The author's experience with spraying for adult spittlebug control has paralleled that reported by other workers. Sprays applied in June, July, and August may result in large initial reductions, but in ten days to two weeks an almost complete reinfestation results. New seedings with sprays applied in early August show the same tendency to reinfestation as do old

Table 1.—Mean number of well formed eggs dissected from each of 10 female spittlebugs.

DATE	NUMBER OF EGGS PER FEMALE
August 24	3.2
September 1	10.5
September 11	20.6
September 13	20.6
October 2	17.7
October 19	20.2
November 2	21.1

[1] First, second, and third year designations are applied to indicate the year of harvest.

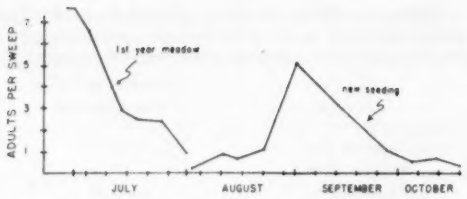

FIG. 1.—Spittlebug populations in two legume fields.

meadows. Data collected in 1949 and 1950 at Wooster, Ohio, show, however, that an application of insecticide during the last week in August or in September will reduce the population and the field will not become reinfested. The adults apparently move over large areas during the period prior to September. After their migration into new seedings where the eggs are to be laid they do not move about enough to cause serious reinfestations of plots from which they have been eliminated.

Data to support the belief that spittlebugs readily infest fields treated in August and do not reinfest fields treated during September were collected from three fields in each of the years 1949 and 1950. All tests were replicated in randomized blocks with plot sizes of 100 by 100, 200 by 110, 70 by 90, 90 by 90, and 50 by 100 feet. Treatment dates in 1949 were August 8, 19, 30 and September 2 and 19. Treatment dates in 1950 were July 27, August 10, 12, and September 2, 3, 13, and 20. The effective insecticides used were DDT and methoxychlor at concentrations varying from 1 to 2 pounds of the technical material per acre. Both materials gave good initial reductions of the adult populations. Sweep samples were obtained from both treated and untreated plots at varying intervals of time after treatment. Most plots were swept weekly through October, although the time interval varied due to the weather and other factors. At least 50 and usually 100 sweeps were made in each treatment at each sampling.

The ratio of populations in the treated plots to those in the untreated plots was then computed and the increase in this ratio used as a measure of reinfestation. To conserve space, only a typical portion of the data is presented. In the graph (Fig. 2) the ratios of treated to untreated populations are plotted against time.

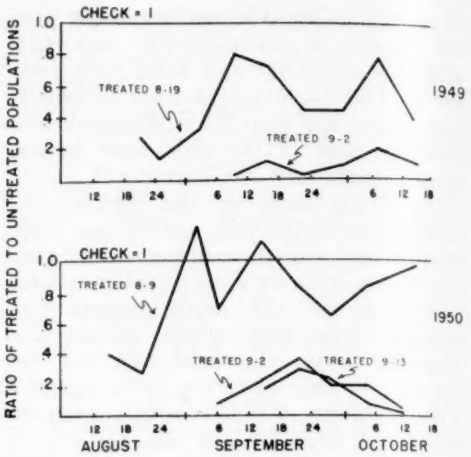

FIG. 2.—Time of treatment and recovery of spittlebug populations.

Ratios from three sprayed populations in 1950 and two in 1949 are shown. In 1950, the population in the plots treated August 9 soon recovered to equal that of the check. Populations of plots treated on September 2 and 13 never recovered. In 1949, the data from figure 2 show that adult spittlebug populations in plots treated on August 19 recovered to some extent but never equalled the check while those treated on September 2 never recovered.

Because of the distributional nature of the ratios involved, ordinary statistical tests of the recovery rates are not applicable. Mr. Paul Moranda, Statistical Laboratory, Ohio State University,[1] suggested and applied a non parametric test described by Mann (1945). Two uses are made of this test. The first is for detecting whether or not the ratios of treated and untreated populations associated with a fixed interval of time after the spray date (*e.g.* 1–10, 11–20 . . . 61–70 days after the spray date) decrease as the date of spraying becomes later. The second use of the test is for detecting whether or not for a given field the ratios tend to increase with time following treatment.

According to Mr. Moranda's computation and interpretation there was evidence of a downward trend in ratios associated with a fixed interval of time after the spray date as the date of spraying

[1] The assistance of Donald R. Whitney in the statistical treatment is gratefully acknowledged.

becomes later. An exception to this occurred. No downward trend was noted in the interval of time 1 to 10 days following treatment. This indicated that all the treatments probably reduced the populations to about the same level and that this level is maintained for a short time after treatment.

The second use of the test showed an upward trend in the ratios, indicating that reinfestation occurred, in the fields sprayed August 19 or before. Fields treated August 30 or later showed no such trend. Both applications of the test support the conjecture that the later the spray date the less reinfestation of the plots.

The fact that adult spittlebug populations can be reduced and maintained at a low level by one application of insecticide in late August or early September would be of no practical value if substantial numbers of the eggs of the insect were laid prior to that time. Osborn (1916) did not observe any spittlebug eggs being laid through the month of August in Maine. He stated that well developed eggs were not found in dissected specimens before August and that by the middle of August only occasionally are eggs with well formed shells to be found within the females. Mundinger (1946) reported that oviposition began in July but was most intensive in September and October in New York.

The author has never observed spittlebug eggs in the field prior to September. The fact that none were observed does not constitute proof that they are not present in the field before that time. Dissections of adult females were made by the author during the summer and fall of 1950 to determine when the eggs developed within the female. No well formed eggs were found within any dissected females prior to August 24. On August 24 a total of 32 well formed eggs were found within 4 of 10 females dissected. Table 1 shows the numbers of eggs found on seven different dates.

Apparently maximum egg development is reached during the first 10 days in September and is maintained until cold weather kills the insects. Probably no oviposition occurs prior to the development of mature eggs, therefore it seems reasonable to assume that adult female spittlebugs do not lay substantial numbers of eggs until September under Northern Ohio conditions.

Since the development of eggs of the spittlebug is coincident with the lessening nomadic activity of the insect, one insecticide application, timed to take advantage of these events, should result in good control of the species by reducing the number of eggs laid and the subsequent nymphal infestation the following spring. The efficacy of such treatments will be reported in another paper.

SUMMARY.—Under northern Ohio conditions, heavy populations of adult spittlebugs build up in newly seeded legume fields during the last of August and the first of September. The majority of eggs are laid in the newly seeded fields which have a residue of straw and stubble from the grain harvest. Control measures applied to fields prior to the September build-up are ineffectual because of reinfestation from surrounding untreated areas. Little or no reinfestation occurs if insecticides are applied after the last of August. The development of eggs within the female is simultaneous with the adult migration into the new seedings. These facts should be useful in timing the treatment of fields containing egg laying adults as a means of reducing the resulting nymphal populations.

LITERATURE CITED

Mann, H. B. 1945. Non parametric tests against trend. Econometrica **13**(3): 245–59.

Mundinger, F. G. 1946. The control of spittle insects in strawberry plantings. JOUR. ECON. ENT. 39(3): 299–305.

Osborn, Herbert. 1916. Studies of life histories of frog hoppers in Maine. Maine Agr. Expt. Sta. Bul. 254.

Pielou, D. P. 1950. The effect of insecticide applications on the insect fauna and seed yield of alsike clover in southern Ontario. Can. Ent. **82**(7): 141–60.

Wilson, M. C. 1949. Organic insecticides to control alfalfa insects. JOUR. ECRN. ENT. **42**(3): 496–8.

Effectiveness of New Organic Insecticides in Controlling Plum Curculio Infesting Plums

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The plum curculio, *Conotrachelus nenuphar* (Hbst.), is by far the most destructive insect pest of plums in Ohio. Crop losses caused by this insect pest has been one of the major factors in preventing the expansion of the plum industry in the state. In the most severely infested areas yields have been seriously decreased by curculio injury, and by the resultant distribution of brown rot, in spite of a vigorous lead arsenate control schedule. The experimental program during the past five years has been devoted to the evaluation of new organic insecticides for the control of the curculio infesting both peaches and plums. The results of investigations conducted on plums in 1946 and 1947 have previously been reported by Neiswander (1948) while the present paper presents information accumulated from 1948 to 1950.

Field investigations were conducted in a mixed variety plum orchard set out in 1940 which was located at the Luchsinger Fruit Farm in the Danbury fruit belt. This orchard consisted of 120 bearing trees arranged in eight rows of approximately 16 trees each. Six and one-half rows were made up of the Stanley variety while the remainder consisted of Albion. The orchard was divided into 32 plots each of which contained four trees in the form of a square. Each treatment was replicated four or five times and the replicates for each treatment were selected at random.

Spraying was begun in the spring when more than 75 per cent of the petals had fallen from the Stanley trees. The treatments were applied with a conventional, high-pressure, hydraulic sprayer using a single nozzle Bean Spraymaster gun. Applications were made from the ground in an attempt to secure adequate and thorough coverage of the fruit on all parts of the tree. Ferbam was used as a control for foliage and fruit diseases since it was considered inadvisable to combine fixed copper and hydrated lime with the chlorinated hydrocarbon insecticides. Good coverage of the trees was obtained with approximately three gallons of spray per tree at the time of petal-fall. As the season progressed it became necessary to increase this amount to a maximum of five gallons per tree.

Treatments were evaluated by determining the relative differences in larval populations in the various blocks. This was done by collecting drop plums at periodic intervals from beneath the sprayed trees. The drops were labeled and transported to Wooster where they were emptied into mesh onion bags. Galvanized iron buckets were placed beneath the bags to collect the larvae as they deserted the fruit. Daily records were taken of larval emergence in each block.

At first, drop collections were made at seven day intervals. However the accuracy of data obtained with this interval was questionable since undoubtedly some larvae had deserted the drop fruits before they were collected. To obtain information on this point an experiment was devised to determine the percentage of larval emergence occurring at daily intervals from plums. This test was conducted in 1949 with Stanley plums and was repeated in 1950 with the Blue Damson variety. Results in both cases were quite similar. Since it was found that only 80 per cent or less of the larvae were being recovered by using the seven day interval the period was shortened to five days. At this interval it was estimated that between 85 and 90 per cent of the larvae were recovered.

Three years' records of larval emergence from drop plums are shown graphically in figure 1. It will be noted that the emergence was considerably higher in 1948 than in either of the two following years. This is undoubtedly due to a higher natural infestation in 1948 as well as the fact that only three applications of each of the treatments were made during that year. In 1949 five applications were made

[1] In cooperation with the Division of Fruit Insect Investigations, Bureau of Entomology and Plant Quarantine, Agricultural Research Administration, Washington, D. C. It is desired to express appreciation to L. D. Luchsinger and S. N. Liann for their excellent cooperation in providing facilities for these investigations. Thanks are also due to James S. Bowman, Charles Gerber, Alan L. Steffen, David Walther and Andrew A. Weaver for their assistance in obtaining records.

while only four were applied in 1950.

In order to make a comparative study of the effectiveness of the materials used in different years it was necessary to restrict the data to given intervals. For example, in 1948, only the larvae emerging from June 22 to July 10 were considered in treatment evaluation. It is evident from figure 1 that for that year the majority of the larvae emerged after July 10 but the apparent lack of control may be attributed to an inefficient schedule rather than to inefficient insecticides. In 1949 the larval emergence was restricted to the period from June 12 to July 1 and in 1950 from June 19 to July 10.

FIELD TESTS IN 1948.—In 1948 parathion, toxaphene, chlordane, technical and refined benzene hexachloride were compared with lead arsenate. The formulations of these materials were: parathion, a 25 per cent wettable powder; toxaphene, a 25 per cent wettable powder; chlordane, a 40 per cent wettable powder; technical benzene hexachloride, a wettable powder carrying 6 per cent gamma isomer and refined benzene hexachloride, a wettable powder carrying 25 per cent gamma isomer. The dosages and evaluation data appear in table 1. An analysis of variance of the larval emergence data showed that all treatments, except technical benzene hexachloride, were significantly better than lead arsenate at the 5 per cent level. Parathion gave the greatest reduction in larval populations although the differences between parathion and other materials could not be shown to be statistically significant. It has been shown that parathion when applied for the control of plum curculio is effective against larvae of the red banded leaf-roller (Rings 1949). Toxaphene, in combination with bone glue, was very effective on plums, but the same spray applied to peaches gave only a 15 per cent reduction of larval populations. The superior performance of toxaphene on plums is believed to have been due in a large measure to the improvement in adhesion achieved by the addition of bone glue.

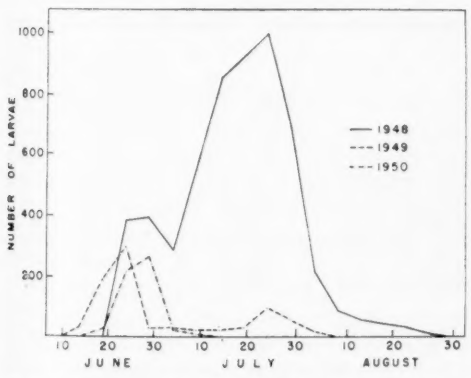

FIG. 1.—Numbers of plum curculio larvae emerging at five day intervals from drop plums.

The effect of variation in spray timing was also investigated by beginning Treatments 7 and 8 ten days after Treatments 3 and 4, which were applied at the time of petal-fall. The value of the later sprays, such as those applied on June 9, is evident from the distribution of the 9148 larval emergence in figure 1.

FIELD TESTS IN 1949.—In 1949 parathion, technical benzene hexachloride, lindane, and chlordane were compared with lead arsenate. The formulations used in 1949 were the same as those used in 1948 except that a lindane wettable powder carrying 12 per cent gamma isomer was substituted for the refined benzene hexachloride and the strength of the technical benzene hexachloride was increased from 6 to 10 per cent gamma. The information relative to spray concentration and field data is presented in table 2. A commercial sticker[2] was included in each treatment, except Treatment 7 at the rate of one pint per 100 gallons to enhance the adhesive qualities of the insecticidal composition. A fungicide was included in each spray at the rate of 1.5 pounds in 100 gallons for disease control. It should be pointed out that the dosage of technical benzene hexachloride was increased from three pounds of 6 per cent gamma used in 1948 to 2.5 pounds of the 10 per cent gamma in 1949.

It may be noted that benzene hexachloride gave the greatest reduction of larvae although very substantial reductions were obtained with lindane and chlordane. All three of these treatments, consisting of five applications, gave significantly better control of larvae than did lead arsenate. Although parathion gave some reduction at the 1 pound rate and considerable reduction at the 2 pound rate the differences between these treatments and lead arsenate were

[2] DuPont Spray Adhesive, E. I. DuPont de Nemours and Company, Inc.

Table 1.—Relative effectiveness of organic insecticides against plum curculio infesting Stanley plums in 1948.

TREATMENT	POUNDS PER 100 GALS.	APPLICATION DATES	MEAN NO. LARVAE PER PLOT	PER CENT REDUCTION OVER LEAD ARSENATE TREATMENT
1. Parathion 25%	2	5-8, 5-18, 5-28	2.5	98.1
2. Toxaphene 25%	4	5-8, 5-18, 5-28	31.3	75.6
3. Chlordane 40%	2.5	5-8, 5-18, 5-28	37.3	71.0
4. BHC 25%	1	5-8, 5-18, 5-28	48.3	62.4
5. BHC 6%	3	5-8, 5-18, 5-28	91.8	28.6
6. Lead arsenate	2	5-8, 5-18, 5-28	128.5	—
Zinc sulfate	4			
Hydrated lime	6			
7. Chlordane 40%	2.5	5-18, 5-28, 6-9	13.8	89.3
8. BHC 25%	1	5-18, 5-28, 6-9	17.3	86.5
Least significant difference at 5 per cent=74.0				

insignificant. The reason for the relatively poor performance of parathion in these tests is unknown.

Timing variation was again studied during 1949 by omitting the petal-fall spray in Treatment 8 and comparing this schedule with Treatment 4 which received the petal-fall spray. In contrast to the results in 1948 it was very definitely shown that a petal-fall spray was of considerable value under the conditions prevailing in 1949.

The effectiveness of a commercial sticker was investigated by comparing one schedule of chlordane with and without a sticker (Treatments 3 and 7). In the former case 1.5 pounds of a commercial sticker was added to each 100 gallons of spray. Since there was but a 4.5 per cent difference in per cent control of curculio larvae it may be concluded that the sticker did not significantly improve the adhesive qualities of chlordane in this instance.

In the chlordane plots spray injury was first noticed on the Albion variety in July. The initial symptoms consisted of a browning of the apex of the leaf which was later followed by a marginal chlorosis which extended approximately one-half of the way to the base of the leaf. When this condition was exceeded defoliation usually occurred. Both plots of chlordane (Treatments 3 and 7) showed injury to the Albion variety but no symptoms were noted in the Stanley plots.

Severe injury to Burbank plums from chlordane was also observed at the Liann Fruit Farm west of Port Clinton in early June. A variety plum orchard, which included Burbank, German Prune, Italian Prune, Waneta and Stanley, was sprayed

Table 2.—Relative effectiveness of organic insecticides against plum curculio infesting Stanley plums in 1949.

TREATMENT	POUNDS PER 100 GALS.	APPLICATION DATES	MEAN NO. LARVAE PER PLOT	PER CENT REDUCTION OVER LEAD ARSENATE TREATMENT
1. BHC 10%	2.5	5-9, 5-17, 5-27, 6-8, 6-20	0.8	97.7
2. Lindane 12%	2	5-9, 5-17, 5-27, 6-8, 6-20	1.5	95.8
3. Chlordane 40%	2.5	5-9, 5-17, 5-27, 6-8, 6-20	2.7	92.4
4. Parathion 25%	2	5-9, 5-17, 5-27, 6-8, 6-20	12.0	66.2
5. Parathion 25%	1	5-9, 5-17, 5-27, 6-8, 6-20	29.8	16.1
6. Lead arsenate	2.5	5-9, 5-17, 5-27, 6-8, 6-20	35.5	—
Hydrated lime	3			
7. Chlordane 40%	2.5	5-9, 5-17, 5-27, 6-8, 6-20	4.3	87.9
8. Parathion 25%	2	5-17, 5-27, 6-8, 6-20	58.3	0.0
Least significant difference at 5 per cent=27.7				

Table 3.—Relative effectiveness of organic insecticides against plum curculio infesting Stanley plums in 1950.

TREATMENT	POUNDS PER 100 GALS.	APPLICATION DATES	MEAN NO. LARVAE PER PLOT	PER CENT REDUCTION OVER LEAD ARSENATE TREATMENT
1. EPN 27%	1.5	5-17, 5-26, 6-5, 6-15	2.0	95.5
2. Parathion 15%	2	5-17, 5-26, 6-5, 6-15	2.4	94.6
3. Methoxychlor 50%	2	5-17, 5-26, 6-5, 6-15	4.4	90.1
4. Dieldrin 15%	1.5	5-17, 6-5	17.2	61.4
5. Aldrin 25%	1	5-17, 5-26, 6-5, 6-15	27.8	37.7
6. Lead arsenate Hydrated lime	2.5 3	5-17, 5-26, 6-5, 6-15	44.6	—
Least significant difference at 5 per cent=23.3				

four times at intervals of six days. The first spray was made up to contain 2.5 pounds of 40 per cent chlordane wettable powder while the remaining sprays contained three pounds of the same formulation. A sulfur fungicide was used in combination with the insecticide for the control of brown rot. Although all of the varieties were critically examined by the orchardist and by the investigator no injury was evident on any of the varieties except Burbank. At the time of examination considerable loss of foliage and fruit had occurred. Some of the leaves remaining on the tree were mottled with reddish-brown areas resembling nitrogen deficiency symptoms to the foliage of stone fruits, while other leaves showed various stages of actual shotholing. Although this injury resulted from several applications of a spray containing a greater concentration of chlordane than is usually recommended it is quite probable that similar, but possibly less severe, injury would have occurred at the approved strength.

Chlordane injury to plums was first reported by Hough (1948) in Virginia who described the symptoms in the French Damson variety. In addition to the evident damage to foliage it was noted that the fruits were but half-size at harvest time. Later Cox (1949) in Pennsylvania stated that two applications of chlordane severely injured the foliage of Fellenberg prune and also retarded the development of the fruit.

FIELD TESTS IN 1950.—As a result of preliminary screening tests conducted in 1949 by the author (Rings 1950), four new materials were introduced into the 1950 field program. These materials were aldrin, dieldrin, EPN and methoxychlor which were compared with parathion and lead arsenate. Aldrin was formulated as a 25 per cent wettable powder, dieldrin as a 15 per cent wettable powder, EPN as a 27 per cent wettable powder, methoxychlor as a 50 per cent wettable powder and parathion as a 15 per cent wettable powder. All of the treatments, except dieldrin, consisted of four applications made at 10 day intervals beginning at petal-fall. Since dieldrin had given such an outstanding residual performance on peach foliage in 1949 two of the regular applications were omitted. The first application of dieldrin was made at petal-fall and the second and last application made 19 days later. The data in table 3 show that the two applications were significantly better than four applications of lead arsenate. EPN, parathion and methoxychlor all gave 90 to 95 per cent reductions in larval populations over lead arsenate. Relatively poor control was obtained with aldrin in comparison with the other materials.

During the middle of July heavy infestations of the mealy plum aphid, *Hyalopterus arundinis* (F.), were noted on certain trees in the orchard. The heaviest populations of the aphid were noted upon trees which had been sprayed with dieldrin. These insects were also abundant in the aldrin and lead arsenate plots and to a lesser extent in the methoxychlor plots. Practically no aphids were present on trees treated with parathion and very few were found on plots receiving EPN.

TASTE TESTS ON STANLEY PLUMS.—In 1948 a cooperative project dealing with

the effect of insecticides upon the flavor of processed fruits and vegetables was established in conjunction with the Department of Horticulture. Through this project it has been possible to secure information relative to the effect of insecticides upon the quality of processed Stanley plums.

Samples of the fruit for taste tests were selected at harvest on the basis of uniformity in ripeness and freedom from insect injury. Although the sampling could not be strictly randomized it was representative of the different areas of the individual trees and of the orchard. These samples were coded and delivered to the Horticultural Products Laboratory of the Department of Horticulture at The Ohio State University. Here they were prepared for canning and subsequently processed according to acceptable commercial practices. After processing they were stored at room temperatures for a period of three months prior to flavor evaluations.

The taste panel used to evaluate these samples was composed of students and faculty of the Departments of Horticulture and Home Economics. Panel members worked individually in booths and scored samples from 1 to 10. A score of one was unsatisfactory and a score of 10 represented perfect flavor. In 1948, plums were tasted on but one occasion but in 1949 each sample was repeated three times by each panel member. Samples treated with lead arsenate were used as a standard for comparison although the identity of this sample was unknown to judges at the time of tasting. A sample was considered to be off-flavor if the sample mean was significantly different from the standard mean at the 1 per cent level.

In 1948 off-flavors were detectable in processed plums from three of the treatments. All of these were directly traceable to the effects of a particular insecticide. Three applications of chlordane at the rate of 1 pound actual toxicant produced a slight off-flavor even though the applications were not made within 90 days of harvest. Two panel members detected an off-flavor in samples treated 90 days before harvest while four members recorded off-flavor in samples treated 78 days before harvest. In a fruit sample which received five applications of chlordane no serious impairment of flavor was noted. The only explanation for this apparent inconsistency is that this sample was taken from another orchard where a lower volume of spray was used. Benzene hexachloride did not contaminate fruit flavor if the treatments were relatively few in number and were not applied within three months of harvest. However, such a schedule was found to be very poor from the standpoint of curculio control. When applications of benzene hexachloride extended up to within 70 days before harvest a very definite musty flavor was imparted to the fruit. Six of the 11 panel members were able to detect the characteristic mustiness.

In 1949 five applications of chlordane imparted an off-flavor to the processed plums although contamination was difficult to detect. Three panel members rated this sample as unacceptable, three members rated it acceptable and the remaining five tended to grade it down although to them it was still in the realm of acceptability. The five application schedule of technical benzene hexachloride seriously impaired the fruit flavor as would be expected from the 1948 results. It should be noted that there was no evidence to indicate that lindane affected flavor and that fruit samples treated with unusually heavy applications of parathion were judged to be as good or better than the standard.

SUMMARY.—Nine of the newer organic insecticides were evaluated over a three year period for the control of the plum curculio, *Conotrachelus nenuphar* (Hbst.), infesting Stanley and Albion plums. Benzene hexachloride was not effective against curculio when used in a three application schedule at a concentration of 0.18 pound gamma isomer in 100 gallons water. When this concentration was increased to 0.25 pound gamma and additional applications made, excellent control of curculio was obtained but the flavor of processed plums was seriously impaired. Lindane at a gamma concentration of 0.24 pound and refined or high gamma benzene hexachloride at a gamma concentration of 0.25 pound gave good control of plum curculio. Neither of these materials imparted a detectable off-flavor to the processed product. Chlordane at a concentration of 1 pound actual toxicant was very effective against curculio but caused moderate to severe injury on several varieties and its use on Stanley

plums imparted an undesirable flavor to the fruit. Parathion when used at a dosage of 2 pounds of 15 per cent wettable powder controlled curculio extremely well except when in combination with a commercial sticker. There was no indication of foliage or fruit injury or flavor contamination in Stanley plums which were sprayed five times at 10 day intervals with 2 pounds of 25 per cent parathion wettable powder in 100 gallons of water. One season's experience with EPN at the rate of 1.5 pounds of a 27 per cent wettable powder in 100 gallons of water indicates that it is about as effective as parathion. Dieldrin used at a concentration of 1.5 pounds of 15 per cent wettable powder proved to be quite promising in 1950 field tests even when half the usual number of applications were used. However it became necessary to use parathion to control infestations of the mealy plum aphid which developed on plots treated with dieldrin. One pound of 25 per cent aldrin wettable powder was not significantly better than lead arsenate and this material failed to control aphid populations. Methoxychlor gave very good results when employed in a four application schedule at the rate of 1 pound of actual methoxychlor per 100 gallons. Toxaphene in combination with a sticker gave good control of curculio in 1948 but was not tested further because of its poor performance on peaches that season. In one test made in 1949 a commercial sticker failed to improve the efficiency of chlordane in controlling plum curculio. Limited tests relative to the timing of applications indicate that it is advisable to begin spraying for curculio at the time of petal-fall. Two to four additional applications, depending upon the severity of the infestation, applied at 10 day intervals are required for commercial control.

LITERATURE CITED

Cox, James A. 1949. Control of plum curculio on prunes. JOUR. ECON. ENT. **42**(4): 632–5.

Hough, W. S. 1948. Chlordan compared with parathion on plums. JOUR. ECON. ENT. **41**(6): 983–4

Neiswander, R. B. 1948. Plum curculio on peaches and plums in Ohio. JOUR. ECON. ENT. **41**(3): 450–3.

Rings, Roy W. 1949. Red-banded leaf roller injury to peaches and plums. JOUR. ECON. ENT. **42**(4): 701–2.

Rings, Roy W. 1950. Residual action of organic insecticides against plum curculio. JOUR. ECON. ENT. **43**(1): 70–2.

Insecticides for Control of White Grubs[1]

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The larvae of *Phyllophaga* and related species have caused very severe losses in seedlings and transplants in Wisconsin forest tree nurseries, in some years destroying as much as 25 per cent of the total stand. Studies of the ranges of host plants of the June beetles, lengths of flight periods, and distances of flight showed that it would be best to direct efforts towards controlling the grubs in the soil. Since prolonged toxicity in the soil is necessary for adequate control of white grubs in tree nurseries, emphasis has been placed on determining the residual effectiveness of the materials. Cage tests of the effectiveness of soil insecticides for grub control have been in progress at a state forest tree nursery in central Wisconsin for the past 4 years.

When insecticides were tested against different stages of larvae it was discovered that the toxicants were most effective just after the insects hatched and became less effective as the grubs matured. The high degree of resistance of the third instar is illustrated by the fact that in one case a 10 per cent survival of third instar grubs was found 36 days after the cages had been treated with parathion at a rate of 108.2 pounds per acre. Results of tests with soil fumigants, of preliminary laboratory and field treatments for control of adults, eggs and larvae, and of cage trials during the first two seasons were reported in 1950 (Shenefelt & Simkover). Consequently, only the results

[1] Results of a cooperative project between the College of Agriculture of the University of Wisconsin and the Wisconsin Conservation Department. Approved for publication by the Director of the Wisconsin Agricultural Experiment Station.

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obtained in field cages and the effects of field applications made in four state forest tree nurseries are included here.

The field cages used, constructed of aluminum frame and screen, consisted of a 2′ by 2′ by 2′ lower portion set in the ground and an upper portion of the same size. Where dusts or wettable powders were tested, the top 3 inches of soil in each cage was removed, sifted, and the amount of insecticide necessary to give the desired dosage in pounds per acre (calculated from the table given by Fleming & Baker 1936) thoroughly mixed with it. The treated soil was replaced and the cage sown with mixed grass seed. After sod had become established the cage was stocked with insects.

Where emulsions or solutions were employed, sod was established, the grubs introduced, and, about a week later, the appropriate amount of insecticide was applied in one gallon of water by sprinkling. The material was then washed into the soil by further sprinkling with 2 gallons of water.

During examination of cages the soil was removed and sifted to a depth of 8 to 10 inches, the top 3 inches being kept separate and replaced on top after the lower layer was returned to the cage. Each cage was reseeded with grass immediately after the soil was sifted.

The tests to be discussed which have been made in these cages for control of grubs are of two types: 1) initial tests for toxicity against first instar grubs; and 2) residual effectiveness.

In the initial tests for toxicity to grubs, 25 first instar larvae, taken from rearing cages, were introduced into the soil in each cage. Approximately 2 weeks later the soil was sifted to determine the survival of the grubs. In certain instances, the grubs found alive were reintroduced into the cages from which they were taken and a second examination made about a month later.

Tests for residual effectiveness of the insecticides have been termed "residual-establishment" since they were designed not only to determine the length of persistence of the insecticide but also the ability of the insecticide to prevent establishment of the grubs by acting on adults, eggs or larvae. In most instances, these tests were conducted in cages which had been treated previously and used in the initial tests for toxicity. However, for certain dosages or formulations the residual-establishment test was used from the beginning. Adult beetles taken from vegetation were placed in the cages in the spring and periodically fed appropriate foliage. Equal numbers of each species and sex were introduced into each cage during a given year. After oviposition and hatching had been completed, as shown by rearing cages used to obtain first instar grubs, and the young grubs had been exposed to the treated soil for a period of approximately 2 weeks (more or less, depending on the time of egg deposition and hatching) the soil in the cages was sifted and the numbers of live grubs recorded. The living grubs were reintroduced, the cage reseeded and a second examination made a month later.

In most instances the adults (collected from vegetation) were able to survive in the cages for a long period and successfully oviposit in the treated soil. In certain cases, as in cages treated with aldrin or dieldrin the year the adults were introduced, death was quite rapid with a 90 per cent mortality occurring during the first three days. However, after aldrin and dieldrin had been in the soil a year, such rapid mortality was not observed. The mortality rate was obtained by observing the dead adults on the surface.

At the present time 206 cages are in use and the tests are being continued. The percentages of control obtained are given in table 1. These percentages were calculated by the following formula:

$$100 \times \frac{\text{No. grubs in control—No. grubs in treatment}}{\text{No. grubs in control}}.$$

Unless otherwise indicated, the per cent control is based on the average of four replicates. It will be observed that there are decided differences between the results obtained at the first and second examinations. These differences may be due in part to an insufficient time of exposure of the newly hatched grubs. But the authors believe that, in general, the figures obtained at the first examination indicate the relative speed with which the young grubs are killed. Since there is a great and variable mortality when the cages are disturbed, the writers believe that the figures obtained at the first

Table 1.—Per cent white grub control obtained with soil insecticides in field cages. Griffith State Nursery, Wisconsin Rapids, Wisconsin, 1947–1950.

Insecticide	Pounds per Acre	Mode of Applic.	Initial Tests Against First Instar		Residual-Establishment Tests							
					First Year		Second Year		Third Year		Fourth Year	
			1st Reading	2nd Reading	1st Reading	2nd Reading	1st Reading	2nd Reading	1st Reading	2nd Reading	1st Reading	2nd Reading
Lead arsenate	500	mixed in	75.0[1]				−8.8	85.4	85.2	88.8	39.5	28.0
	1000	mixed in	42.3				96.1	97.5	75.8	76.0		
Chlordane	0.5	mixed in			63.1	78.8						
	1	mixed in			66.3	76.9						
	2.5	mixed in	100[1]				100		100		92.8	93.5
	10	mixed in	100				100		97.2	100		
	10	emulsion	86.5				100		85.2	100		
Aldrin	1	mixed in			98.8	100						
	10	mixed in			100		99.9	100				
	10	emulsion	100				99.1	100				
Dieldrin	1	mixed in			94.8	98.2						
	10	mixed in			99.7	100	99.0	100				
	10	emulsion	83.3	100			97.4	100				
γBHC	0.25	mixed in	100[2]									
	0.5	mixed in	100[2]									
	1	mixed in	100[1]				100		98.3	98.8	73.3	98.2
	1	emulsion	53.8				100		96.9	100		
DDT	5	mixed in					46.2	43.8				
	10	mixed in	−50.0[1]				73.1	79.2				
	10	emulsion	−21.2									
	25	mixed in	−62.5[1]				−23.1	41.7				
TDE	10	emulsion	− 9.6				−77.0	−91.5				
Toxaphene	10	emulsion	−17.3				23.5	74.5				
	20	mixed in			96.1	98.2	89.1	92.6				
	20	emulsion	83.3	90.9			57.4	93.3				
Parathion	2.5	mixed in	90.4				89.6	95.0	61.3	22.5		
	2.5	w.p. sprinkled on soil					73.8	90.7				
	100.2	1/1000 sol. sprinkled on soil					100		85.4	85.2		
DPP[3]	50.4	1/2000 sprinkled on soil					99.6	100				
AC 4049	5	mixed in	−3.33	30.0								
	10	mixed in	30.0	90.0								
Sulphur	500	mixed in			7.7	50.0						
Penothiozene	10	mixed in	86.5				−35.7	87.1				
Mercurous bichlor.	8.85	1/1000 sol. sprinkled	15.4[4]				−25.2[4]	−22.9[4]				
NMRI-448	10	emulsion	3.8[4]									

[1] Based on a single control cage.
[2] 10 first instar larvae used per cage.
[3] diethyl paranitrophenol phosphate.
[4] Only 2 cages treated.

examination are more valid than those of the second. When a treatment was considered ineffective the cages were completely emptied and fresh soil introduced so that other tests might be conducted. The point at which tests were discontinued is indicated in the table by a solid bar following the last percentage of control given.

The tabulated data shows that, in Plainfield sand: (a) lead arsenate, long considered as a standard for grub control, loses its toxicity more rapidly than either chlordane or benzene hexachloride; (b) the toxicity of chlordane mixed into the soil begins to decline at the end of the third season; (c) benzene hexachloride at 1 pound of the gamma isomer per acre loses its insecticidal properties to a greater extent than chlordane at 2.5 pounds per acre between the third and fourth seasons; and (d) in general, wettable powders mixed into the soil retain insecticidal properties longer than emulsions of the same materials and at the same dosages applied from above and washed into the soil.

Of the materials tested which appeared to give effective control, lead arsenate and benzene hexachloride cannot be recommended for use in conifer producing nurseries because of phytotoxicity or adverse effects upon soil organisms.

Preliminary field tests with chlordane indicated the necessity of having the insecticide in the ground before heavy feeding of the grubs commenced. Emulsions applied in 1948 after damage became visible did not prevent severe losses although as much as 14 pounds of actual chlordane was applied per acre. In contrast, an emulsion applied at 12 pounds per acre just before heavy feeding began prevented damage although a greater grub population was present than in the areas treated after the appearance of damage. Although there were many surviving grubs, *i.e.*, the dosage was

sublethal for many of the individuals, they did not feed in the normal manner and no measurable damage occurred. A large percentage of the grubs in this area survived to become adults. An entirely unexpected result was obtained in 1950 when these adults were found to die (without feeding or laying eggs) within a few days after emerging from the treated soil. A total of 1281 specimens (mostly *Phyllophaga tristis* (Fab.)), including 702 females, were collected from the treated soil at the time of emergence and placed in untreated soil in rearing cages and fed proper foliage. That their behavior was abnormal was evidenced by the fact that they refused to feed and were unsuccessful in entering the soil after a few nights. Over 90 per cent were dead by the time the major flight was occurring in the field. From these beetles only eight eggs were obtained and none of these hatched. This contrasted sharply with the number of eggs obtained from normal beetles, with the way in which they feed in cages, and with the length of life of normal individuals.

In the field where chlordane treatments (both dusts worked into the soil and emulsions) had been applied, numerous adults were observed during the day on the surface of the ground. Many were on their backs and showed symptoms of poisoning. The number of dead and dying beetles increased until four or five dead adults per square yard was not uncommon. This unexpected result indicates the desirability of a study of the ultimate effects of sublethal dosages on the entire life cycle in order to work out dosages which will give adequate (or ultimate) control.

Severe damage was anticipated in 1950. Consequently, all areas which became free from trees during the fall of 1949 and the spring of 1950 were dusted with chlordane at 10 pounds actual per acre, using a row crop power duster. Immediately after the application of the dust, the material was worked into the soil to a depth of about 8 inches by means of either a disc or a rototiller. Areas containing trees which were to remain in the seedbeds a second year were treated with chlordane emulsion at 6 pounds actual per acre. This treatment was applied by means of the overhead sprinkling system.

Excellent results were obtained from the applications, with practically no grub damage occurring in any of the four state nurseries during the past season. In an untreated private nursery near one of the state nurseries, however, damage was extensive.

SUMMARY.—A number of the chlorinated hydrocarbons have been shown to give adequate white grub control in field cages operated for the past four seasons.

Since chlordane has proved effective for a 4-year period in cages, has afforded protection against grub injury in the field, and has been demonstrated to be non-phytotoxic to a wide range of tree seedlings, it has been recommended for use in forest tree nurseries.

LITERATURE CITED

Fleming, W. E. and F. E. Baker. 1936. The effectiveness of various arsenicals in destroying larvae of the Japanese beetle in Sassafras sandy loam. Jour. Agr. Res. **52**(7): 495.

Shenefelt, R. D. and H. G. Simkover. 1950. White grubs in Wisconsin forest tree nurseries. Jour. Forestry **48**(9): 429–34.

CHANGE IN NAME OF ENTOMOLOGY DEPARTMENT AT WISCONSIN

A change in name of the Department of Economic Entomology to the Department of Entomology was recently approved by the Board of Regents at the University of Wisconsin. The request was made by unanimous recommendation of the entomology staff members on the basis that the curriculum offered no longer consists principally of economic phases of entomology and that expansion in both teaching and research has resulted in almost a complete curriculum in entomology comparable to that offered by other major institutions. Furthermore, entomology as a field for specialization is not different in principle from the fields of genetics, bacteriology, plant pathology and others. The omission of the word "economic" from the department name also avoids possible confusion with other departments or schools such as Economics, Agricultural Economics, and Home Economics.

The approved name conforms more aptly with present teaching and research activities in entomology according to Dr. T. C. Allen, Chairman of this department, at the University of Wisconsin.

Late Season Control of European Red Mite

C. R. CUTRIGHT, *Ohio Agricultural Experiment Station, Wooster*

As the rate of population development of the European red mite decreases in late August and early September, the possibility of serious attack and damage likewise declines. However, the date on which control measures cease to be profitable varies greatly from year to year and from orchard to orchard. Growers are always interested in this problem and continually harass agricultural agents and extension specialists for definite information on the date when spraying is no longer necessary.

Four major conditions influence the date on which control operations may safely be discontinued. These are: (1) number of mites present; (2) condition of the food (foliage) available to the mites; (3) presence and number of natural enemies; and (4) type of acaricidal material in use in the orchard.

Minor conditions that also influence the date of control measure cessation are: (1) varieties grown in the orchard; (2) duration and intensity of the present mite population; and (3) the period of oviposition for the overwintering eggs.

NUMBER OF MITES PRESENT.—The first factor is of course modified tremendously by the others but for practical analysis it should be considered without their inclusion. The ability of populations of different numbers to develop to damaging proportions over given periods of time is the thought to be kept in mind. How long will it take an unopposed population averaging 0.1 mite per leaf or one of 5 mites per leaf to increase to dangerous numbers? Is the rate of this increase the same during the different months of the growing season? Some answers to these questions may be had by studying the course of observed infestations where they occur with little interference from other factors.

Figure 1 shows population development and decline over an entire season in commercial orchards. The early season populations (lines A and B) started with an abundant food supply of good quality, with practically no natural enemies, and were not subject to the action of acaricidal sprays. The decline in numbers in midsummer is due almost entirely to the failure of the food supply. In the same figure (lines C and D) there is also shown the course of populations developing in late season. These started with the same low numbers and with the exception of the season all other factors were apparently equal. However, these populations never achieved great numbers and their duration was much less. In general the differences between unopposed populations that start at different seasons of the year are well illustrated by this figure.

When high populations are found on the

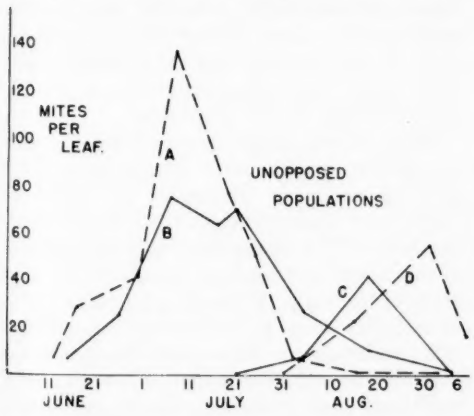

FIG. 1.—Examples of the development and decline of European red mite populations starting at different dates during the season.

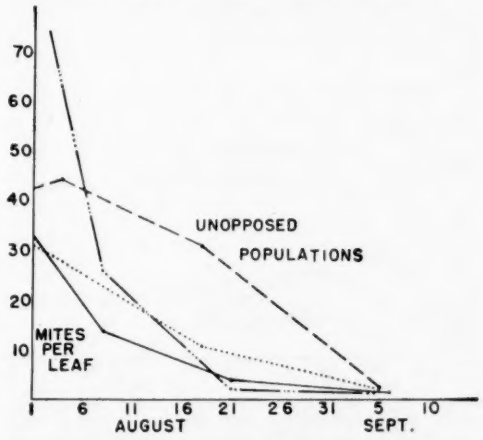

FIG. 2.—High populations of the European red mite practically always decline during the month of August.

trees from early to mid August, these practically always decline as is shown in figure 2.

The questions of most interest to the grower, however, are those dealing with the populations that may develop in late August or early September. Will an infestation develop and will control measures be necessary? On August 1, most Ohio growers consider that the spray season is practically past and that a low population of mites will not develop to dangerous proportions. In figure 3 the development of populations starting in early August with negligible numbers is shown. From this it can readily be seen that population development may vary widely. Line A of figure 3 shows the development of a tremendous mite population in a short time, while line B shows a population that failed to increase. The other lines show intermediate development. These illustrations came from different seasons but except for this difference other factors seemed to be the same. Population increases of any significance have seldom been observed after September 1.

Though heavy populations may develop in late season, the damage that they do is appreciably less than that done by populations of the same size in early or mid season. Numerous cases have been observed in which trees tolerated populations of from 20 to 40 mites per leaf for periods as long as 10 days without commercial damage being done. Such a case is illustrated by line C, figure 1.

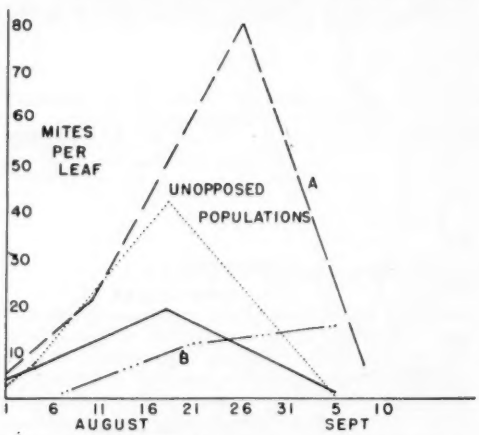

FIG. 3.—Numerically low and unopposed mite populations practically always increase during the month of August. However, there is much variability in the rate of development.

FOOD CONDITION.—A heavy population of mites will exhaust the supply of prime food in a period of from ten to twenty days. This is the most important factor in the natural decline of most heavy mid-season populations, and illustrations of this are shown in figures 1 and 2. Mites on severely injured foliage do not feed normally and the damage they do is of small amount. Many growers do not recognize this fact and much money, effort, and materials are wasted in control efforts after the damage has already occurred. On the other hand, lightly injured foliage will rejuvenate itself if the mites are removed by prompt and effective control measures.

NATURAL ENEMIES.—The principal natural enemies of the European red mite in Ohio are the ladybird beetle, *Stethorus punctum* and its larvae, the larvae of *Chrysopa oculata*, at least one species of predaceous thrips, and at least three species of predaceous mites. All of these work most effectively in noncommercial orchards where spraying is kept at a minimum. Predators are hampered tremendously by thorough spray schedules. An early season application of oil that is effective against eggs of the European red mite will force a potentially effective group of predators to leave the orchard because of lack of food. Sulfur fungicides are hard on predaceous mites and all predator species suffer from the use of DDT and other chlorinated hydrocarbons and phosphorus compounds. Their appearance in effective numbers in an infested orchard frequently occurs only after severe damage has been done by the mites and when the population is declining naturally, due to poor food.

Only rarely do predators hold a mite population within safe limits in a commercial orchard. Examples of such orchards are shown in figure 4. However, in the case of the upper line, one application of a dinitro acaricide was needed to help control the mite population in early June. It is fairly easy to determine whether or not predators are numerous enough in an orchard to effect control. However, the rarity of such instances makes predators an entirely unreliable source of control, especially in late season.

ACARICIDAL SPRAY MATERIALS.—During the past 5 years great improvements have been made in spray materials used in the control of mites. We now have at hand several very effective chemicals, any of which can be used according to the demands of the situation. A thorough application of dormant oil will usually control mites up to mid July or even later. However, in many instances of its use, some additional control in late season will be needed. When no early season oil is used, at least two applications of an effective acaricide will be needed, usually in June. Such a program will also control the mites till late season.

Whether or not spraying must be done in August and, if so, how many applications, are the questions that interest the grower. The results of spraying in late July and in August against healthy populations of European red mites are shown in figures 5, 6, 7, and 8. In figures 5 and 6 the results of spraying against mites in 1946 and 1947 are shown. At that time the acaricides in common use were much less effective than those that are now available. Check plots in these experiments were severely damaged by mites. On the other hand, commercial control was secured even with the less effective acaricides (line A, figures 5 and 6). Two sprays were considered necessary for control, though the repetition of the spray illustrated by line B in figure 6 might not have been necessary. Line B in figure 6 shows data taken from a plot sprayed with dimethyl carbinol, one of the best acaricides of that time.

Figure 7 shows the results of an experiment in 1949. Line B in this figure gives the performance of ethyl p-nitrophenyl thionobenzenephosphonate (EPN), one of the best acaricides of today. It is obvious that the second spray application of August 4 was unnecessary.

In figure 8 data from 1950 plots that received only one late season spray are presented. Effective materials gave excellent control to the end of the season. Figure 8 also shows the results of attempted reinfestations on EPN plots. Hundreds of mites were placed on these plots on August 4 and on August 22 (fig.

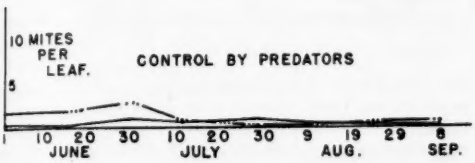

FIG. 4.—Natural control of European red mite population in two orchards where predaceous enemies were abundant.

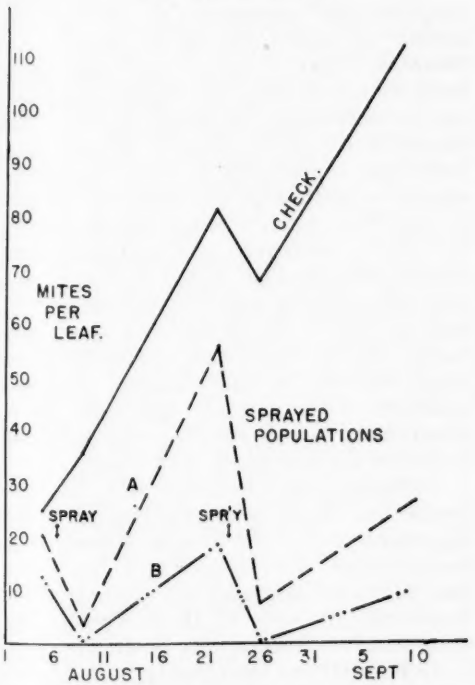

FIG. 5.—Effect of acaricides on European red mite populations.

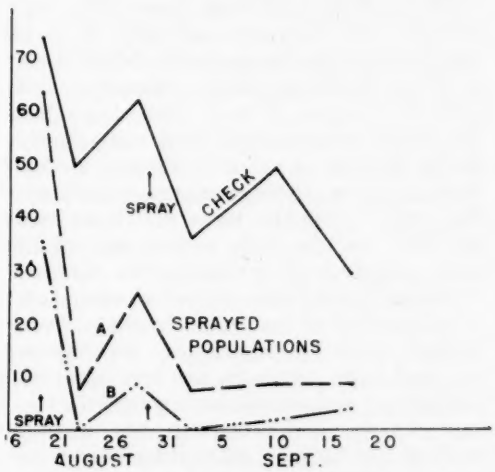

FIG. 6.—Effects of acaricides on European red mite populations in late season.

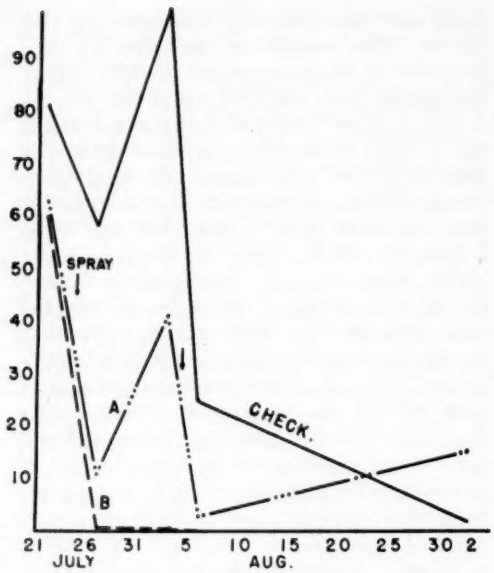

FIG. 7.—Effect of different acaricides on late season populations of European red mite. Line B illustrates a very effective material.

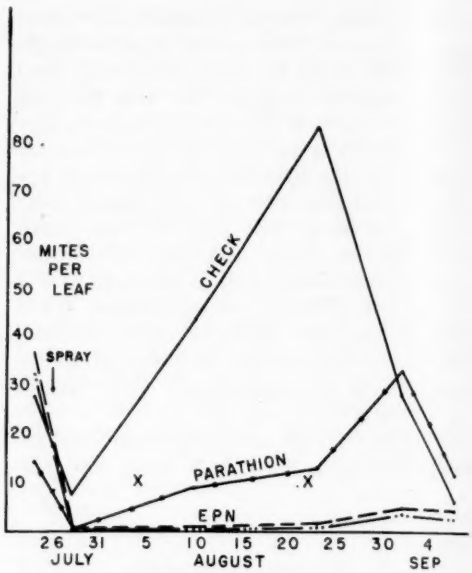

FIG. 8.—Effect of acaricides on European red mite populations. Trees sprayed with ethyl p-nitrophenyl thionobenzenephosphonate (EPN, dash line), were reinfested on dates indicated by X. Other plots were not reinfested.

8-X). The first reinfestation was 9 days after spraying and practically none of the mites survived. The second was made 27 days after spraying and only a few mites survived. No reinfestation was made on the parathion plots or on the EPN plots illustrated in figure 8 by the dash-dots line. The comparison with the increase of population on parathion sprayed plots indicates that residual action was still in effect on the EPN series.

Minor factors at times are quite important. The European red mite shows a considerable preference for Red Delicious, Golden Delicious, Rome Beauty, and related varieties. It is on these trees that the most severe infestations are usually found in late season. Therefore in orchards where these varieties constitute the majority of the trees, the European red mite may be more serious and might need a control spray even in late August.

Orchards that have carried a population over a period of one to two months, even though such a population has never reached large numbers, are less likely to experience sudden damaging increases in late season. Unfortunately, the grower seldom has the necessary information on mite populations to evaluate this factor.

Deposition of the overwintering eggs varies widely as to starting date in different orchards and seasons. Also, the proportionate amounts of oviposition during the season fluctuates greatly. At Wooster, Ohio, overwintering eggs have been found as early as August 14. This was on trees where the foliage was severely damaged by mites. Ten to fifteen days later eggs can usually be found in all orchards regardless of the condition of the leaves. Population declines are inevitable as soon as numerous overwintering eggs appear, and thus the factor of oviposition may influence the use or lack of use of late season sprays. However, this does not mean that the deposition of summer eggs stops entirely in late August. Limited numbers of the summer eggs have been observed in late September and hatching as late as the first week in October.

SUMMARY AND CONCLUSIONS.—The increase and decrease of populations of the European red mites in late season have been studied over a period of ten years and factors responsible for decreases determined. In view of these studies the following conclusions may be drawn.

1. Populations developing in late season may be serious but never as dangerous as those that develop in June and early July.

2. Trees are more tolerant of late season populations.
3. Predators are a factor of minor importance in late season control.
4. Populations do not increase appreciably after September 1.
5. One spray application of an effective acaricide after August 1 will give commercial control.
6. Spraying after August 25 is seldom necessary.

Tests of Insecticides for Control of Cotton Insects During 1950[1]

J. C. GAINES, H. A. DEAN and READ WIPPRECHT, *Texas Agricultural Experiment Station, College Station*

During 1950, investigations have been continued at this Station in an effort to determine the efficiency of a number of insecticides and insecticidal mixtures when applied both as sprays and dusts for the control of thrips, *Frankliniella tritici* (Fitch), boll weevil, *Anthonomus grandis* Boh., bollworm *Heliothis armigera* (Hbn.), and the red spider mite *Septanychus texazona* McG.

Results of tests conducted by Gaines *et al.* (1948) indicate that toxaphene as well as a number of other organic insecticides were effective in the control of thrips. The yields were not significantly increased by the control of thrips. However, the treatments protected the cotton from injury and allowed normal fruiting. Dean & Gaines (1950) obtained results which showed that certain organic insecticides when applied as sprays were equally effective as when applied as dusts for boll weevil and bollworm control. Toxaphene-DDT (2-1) spray gave better control of the bollworm than toxaphene. Higher yields were obtained with the mixture than when toxaphene was used alone. Gaines *et al.* (1950) reported the results of laboratory tests conducted to evaluate a number of compounds for the control of the spider mite. The most effective of these materials were tested in the field.

Tests herein reported were designed to obtain further information with regard to the efficacy of insecticides when used both as sprays and dusts and also to compare new insecticides with those already in use. The field tests were conducted in the Brazos river bottoms near College Station during the 1950 season. The dust applications, using rotary hand guns, were made early in the morning while the plants were wet with dew. Spray applications were made during the day without regard to wind movement. A small compressed air sprayer mounted on two wheels was used to apply spray on small plats while a tractor sprayer or airplane served on the larger plats.

The sprayer mounted on two bicycle wheels consisted of a 9-gallon compressed air tank equipped with regulator valve and gauge. The boom and cone nozzle arrangement, three to each row, were similar to those on a tractor sprayer. Spray from the top nozzle overlapped that from the side nozzles, thereby affording thorough coverage of the plants. Sprays were applied at approximately 60 pounds pressure and at the rate of 2.5 gallons per nozzle, per acre. The spray tank was weighed before and after application to determine the dosage.

The 6-row tractor sprayer consisted of a pump coupled to the power take-off shaft, tank and boom assembly with 3 nozzles per row. This sprayer was also operated at 60 pounds pressure with each nozzle delivering about 2.5 gallons per acre. The airplane sprayer carried 28 nozzles on its boom and distributed about 3 gallons of spray per acre in swaths 33 feet wide.

Infestation records and analyses of variance were made in the usual manner. In the laboratory tests, the net percentages of mortality were calculated by Abbott's formula.

The aim of experiment 1, as shown in table 1, was for comparing the effectiveness of the following materials when applied both as sprays and dusts for thrips control: (1) toxaphene, (2) aldrin and (3) dieldrin. A split-plat randomized block arrangement was used in this test. This type of experiment afforded adjacent

[1] Technical contribution No. 1421, Texas Agricultural Experiment Station in cooperation with the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture. Thanks are due C. E. King and R. E. Biggs for assistance in making the field records.

Table 1.—The percentage control of thrips with insecticides as indicated in experiment 1, College Station, Texas.

Treatment	Ave. Rate[1]	Per Cent Control, Days After Application		
		3	7	9
Aldrin				
Dust	.13	96.2	95.0	92.3
Spray	.08	98.9	90.7	87.1
Dieldrin				
Dust	.13	100.0	100.0	99.5
Spray	.09	100.0	99.8	99.7
Toxaphene				
Dust	1.00	99.8	57.9	81.6
Spray	.73	94.0	76.0	70.4

[1] Pounds active ingredients per acre.

comparisons of dusts and sprays as well as valid comparisons of the insecticides. Each sub-plat was 12 rows wide and of sufficient length to make one-tenth acre. Each treatment and each check were replicated four times. Twenty plants were pulled at random from each plat, placed in paper bags and transported to the laboratory. Here the plants were examined and the number of thrips was recorded. The percentages of control were calculated by Abbott's formula.

The sprays proved more effective than the dusts for thrips control. Aldrin and dieldrin sprays at the rates of 0.08 and 0.09 pound per acre proved more effective than toxaphene applied at 0.73 pound per acre. Dieldrin showed more residual toxicity than either aldrin or toxaphene.

In experiment 2, table 2, the purpose was to determine the effectiveness of the following insecticides applied as both sprays and dusts in the control of boll weevils and bollworms: (1) toxaphene, (2) toxaphene-DDT (2-1) and (3) gamma benzene hexachloride-DDT (3-5). The dust mixtures contained 40 per cent sulphur. The split-plat randomized block arrangement was used in this test also. Each plat was 12 rows wide and of sufficient length to make one-tenth acre. Each treatment was replicated four times. The picking area after eliminating buffers was one-twenty-fifth acre. Ten applications of each material were made at approximately 5-day intervals during the period from June 29 to August 21. A heavy boll weevil infestation and medium injury resulting from bollworms occurred during this test as indicated by the severe damage on the check or untreated plats.

Toxaphene, toxaphene-DDT and gamma BHC-DDT dusts proved equally effective. The spray formulation of toxaphene-DDT was as effective as the dust formulations. Toxaphene and gamma BHC-DDT sprays were not as effective as the toxaphene-DDT spray nor the toxaphene or toxaphene-DDT dusts.

A comparison of the detailed records of boll weevil and bollworm infestations on plats treated with toxaphene dust, toxaphene spray and toxaphene-DDT spray is shown in table 3. It will be noted that toxaphene-DDT spray was somewhat more effective against weevils, particularly late in the season and was more effective against bollworms than toxaphene spray alone. Toxaphene dust

Table 2.—The average boll weevil infestation, bollworm injury and yields of seed cotton on experiment 2, College Station, Texas.

Treatment[1]	Ave. Rate[2]	Boll Weevil Infestation	Bollworm Injury	Yield		
		Per Cent Punct. Sqs.	Per Cent Inj. Bolls	Per Plat	Per Acre	Gain Over Check
Check		57.0	9.5	43.0	1075	
Toxaphene						
Dust	2.9	22.5	2.6	91.1	2278	1203
Spray	2.9	30.3	5.0	81.2	2030	955
Tox.-DDT (2-1)						
Dust	3.5	24.0	.9	89.7	2242	1167
Spray	3.0	27.6	2.6	87.2	2180	1105
γ BHC-DDT (3-5)						
Dust	1.4	30.1	2.3	86.1	2152	1077
Spray	1.1	32.7	3.3	81.7	2042	967

[1] Each dust mixture contained 50 per cent sulphur.
[2] Pounds active ingredient per acre.

Table 3.—Comparison of the boll weevil infestation and bollworm injury on plats treated as indicated in experiment 2, College Station, Texas.

Date	Toxaphene Dust		Toxaphene Spray		Toxaphene-DDT Spray	
	Boll Weevil Infestation[1]	Bollworm Injury[2]	Boll Weevil Infestation[1]	Bollworm Injury[2]	Boll Weevil Infestation[1]	Bollworm Injury[2]
July						
7/3	33.0		35.8		43.5	
7/7	5.2		16.0		14.0	
7/12	6.0		9.8		13.2	
7/18	14.2		14.8		22.8	
7/24	29.0		28.8		31.8	
7/28	17.0	3.2	21.2	5.0	16.2	3.5
August						
8/2	14.5	2.0	32.8	1.8	14.8	1.8
8/8	34.8	3.5	57.0	4.8	46.2	2.5
8/14	49.0	3.2	56.8	5.5	46.8	1.8
8/19		1.8		7.0		1.8
8/23		2.0		6.0		4.5
Average	22.5	2.6	30.3	5.0	27.6	2.6

[1] Per cent punctured squares.
[2] Per cent injured bolls.

gave better control of the weevil resulting in higher yields than either toxaphene or toxaphene-DDT sprays.

Laboratory tests were designed to obtain further information on the toxicity of toxaphene and toxaphene-DDT sprays.

Table 4.—Comparison of percentages of mortalities for materials and dosages indicated in laboratory experiment at College Station, Texas.

Dosage	Per Cent Mortality			
	DDT	Toxaphene	Sum of Mortalities for Toxaphene and DDT	Toxaphene-DDT Mixture
.04	11.25			
.06	15.29			
.08	15.73	17.78		
.10	9.25			
.12		10.59	29.03	4.88
.14	17.61			
.16		9.09		
.18	2.82		25.88	4.88
.20		10.91		
.24			24.82	14.94
.28		13.81		
.30			20.16	10.91
.33	6.63			
.36		15.11		
.42			31.42	18.37
.50	11.87			
.54			17.93	19.80
.67	33.64	23.08		
1.00		36.73	29.71	27.17
1.30		45.66		
1.50		35.53	48.60	42.05
2.00		48.61	79.30	61.32

The results of these laboratory tests are shown in table 4. Four replicates were included for each dosage and check cages were included in each series. Each series consisted of dosages of toxaphene and DDT applied separately in the ratio of 2 to 1 to be compared with equal dosages of the toxaphene-DDT (2-1) mixture. The sum of the mortalities for the several dosages of toxaphene and DDT are shown in column 4, table 4. The accumulated percentages of weevil mortalities for toxaphene and DDT were as high as for those of comparable dosages of the toxaphene-DDT mixture. The mixing of toxaphene and DDT did not increase the toxicity for weevil control over comparable dosages of toxaphene and DDT applied separately. Either toxaphene and DDT (accumulated from separate tests) or the toxaphene-DDT mixture proved more effective for weevil control than toxaphene alone, particularly at the high levels of kill.

Experiment 3, as shown in table 5, was designed to compare the effectiveness of the following materials for boll weevil and bollworm control: (1) 20 per cent toxaphene-40 per cent sulphur, (2) 3 per cent gamma benzene hexachloride-5 per cent DDT-40 per cent sulphur (3-5-40), (3) 2.5 per cent dieldrin dust, (4) toxaphene spray, (5) aldrin spray and (6) dieldrin spray. The randomized block plat arrangement was used in this test. Each plat was 12 rows wide and of suffi-

Table 5.—The average boll weevil infestation, bollworm injury and yields of seed cotton on experiment 3, College Station, Texas.

Treatment	Ave Rate[1]	Boll Weevil Infestation	Bollworm Injury	Yield		
		Per Cent Punct. Sqs.	Per Cent Inj. Bolls	Per Plat	Per Acre	Gain Over Check
Check		23.9	18.0	39.5	988	
20% Toxaphene-40% Sulphur Dust	2.80	7.2	2.1	83.1	2078	1090
3-5-40 Dust[2]	1.20	7.6	1.9	86.5	2162	1174
2.5% Dieldrin Dust	.34	8.1	5.3	77.7	1942	954
Toxaphene Spray	2.80	11.1	6.6	66.2	1655	667
Aldrin Spray	.33	12.0	10.9	61.5	1537	549
Dieldrin Spray	.32	8.5	7.8	71.6	1788	800
Min. diff. req. for significance		3.8	1.8	12.3		

[1] Pounds active ingredient per acre.
[2] 3% gamma benzene hexachloride-5% DDT-40% sulphur.

cient length to make one-tenth acre. The picking area after eliminating buffers was one-twenty-fifth acre. Each treatment was replicated four times. Twelve applications of each material were made at approximately 5-day intervals during the period from June 30 to August 26. The first three applications were pre-square applications. A severe bollworm injury and a medium boll weevil infestation occurred during this test, as indicated by the severe damage on the check plats.

Although the boll weevil infestation was not considered heavy, the results indicate that toxaphene spray and aldrin spray were less effective than either toxaphene dust, 3-5-40, dieldrin dust or dieldrin spray. Under the conditions of a heavy bollworm infestation, toxaphene and 3-5-40 dusts were equally effective and both dusts gave significantly better control than either dieldrin dust, dieldrin spray, toxaphene spray or aldrin spray. Using yields as the criterion, toxaphene dust, 3-5-40 and dieldrin were significantly better than aldrin or toxaphene spray.

In experiment 4, table 6, the purpose was to compare the following insecticides or insecticidal combinations when applied as sprays by either tractor or airplane for boll weevil and bollworm control: (1) toxaphene-DDT, (2) aldrin-DDT, and (3) dieldrin-DDT. The plats were about 7 acres in size. Three of the six applica-

Table 6.—Treatments and yields produced on large experimental plats at College Station, Texas.

Experiment	Treatment	Ave. Rate[1]	No. Applications	Average Gain Over Check, Seed Cotton per Acre	Net Profit per Acre
	Toxaphene-DDT (2-1) Spray[3]	3.00	6	787	$ 90
	Toxaphene-DDT (2-1) Spray	2.90	6	775	88
4[2]	Aldrin-DDT (1-2) Spray	.66	6	703	
	Dieldrin-DDT (1-2) Spray	.63	6	733	
5	Toxaphene-Sulphur Dust	2.80	6	672	72
	Toxaphene-DDT (2-1) Spray	3.10	6	835	98
6	Toxaphene-DDT (2-1) Spray[4]	3.50	12	909	91
	Toxaphene-DDT (2-1) Spray	3.70	9	933	102
7	Toxaphene-DDT (2-1) Spray[5]	3.00	10	1223	133

[1] Pounds active ingredients per acre.
[2] DDT was not included in the mixtures for the first three early applications.
[3] Airplane applications.
[4] Three pre-square applications of toxaphene were made at an average rate of 1.2 pounds per acre.
[5] Airplane application. One application of 3-10-40 dust was applied for aphid control.

Table 7.—**The percentage reduction of red spider mites following applications of the material indicated at College Station, Texas.**

Treatment	Rate[1]	Per Cent Reduction, Days After Application				
		2	3	5	7	10
Test Material #1[2]	.25	32.8	52.7	71.8		
Aramite	.25		83.2	83.5	80.9	66.2
Compound R-242[3]	1.00	8.9	29.6	15.9		
Compound R-242	1.00		81.9	90.1	84.9	66.3
Compound 923	1.50		90.7	96.2	89.2	79.0
Compound 6451	1.50		86.6	93.5	92.7	93.7

[1] Pounds active ingredients per acre.
[2] Test Material #1 mixed with toxaphene-DDT emulsion and applied by airplane.
[3] Applied by airplane.

tions were made early in the season when the cotton was small. There was no appreciable difference in the yields produced on plats treated with toxaphene-DDT applied either by airplane or tractor and the plats treated with aldrin-DDT or dieldrin-DDT applied by tractor. The addition of DDT to these materials increased their effectiveness for bollworm control.

Experiment 5, table 6, was designed to compare the effectiveness of 20 per cent toxaphene-40 per cent sulphur dust with toxaphene-DDT spray. The plats were about 1 acre in size and both the dust and spray were applied with tractor machines. Six applications were made at approximately 5-day intervals. Under the conditions of heavy bollworm injury and a comparatively light boll weevil infestation, the toxaphene-DDT spray proved more effective than toxaphene dust.

In experiment 6, table 6, early season control using 3 applications of toxaphene, was applied to one plat followed by nine later applications of toxaphene-DDT for boll weevil and bollworm control. For comparison, another plat received only the nine late applications of toxaphene-DDT spray. There was little difference in the yields on the 2 plats. Both plats produced a significant increase in yield over the check plat resulting in a net profit of from $91 to $102 per acre.

Experiment 7, table 6, was an outstanding demonstration in cotton insect control. Due to adverse weather conditions the cotton in this test was planted late and reached a stand during the first week in June. Infestations of both weevils and bollworms developed causing severe damage to the check plat. Nine applications of toxaphene-DDT (2-1) spray were applied by airplane to 40 acres of cotton, approximately 2 acres of untreated cotton served as a check. An aphid infestation developed in August and 1 application of 3 per cent gamma benzene hexachloride-10 per cent DDT-40 per cent sulphur dust was applied instead of a spray for control of aphids as well as boll weevils and bollworms. At this time a leafworm infestation developed on the check plat and one application of toxaphene (1 pound)-tetraethyl pyrophosphate (0.5 pint 40 per cent) per acre was applied with tractor sprayer for leafworm and aphid control. The 40 acres treated produced an average of 1223 pounds seed cotton per acre more than the check plats, or an average of 122 pounds per acre-application. These treatments produced an average net profit of $133 per acre. The entire 42 acres, including the check, produced an average of 999 pounds lint cotton per acre.

Late in the season, red spider mite infestations developed on some fields of cotton affording an opportunity to test several organic sulphur compounds for their control. The results of these tests are shown in table 7. In two fields, the materials were applied by plane while in the other tests the materials were applied by a tractor sprayer. The following materials were used: (1) (2) (p-tert-butylphenoxy)-1-methyl-ethyl 2-chloroethyl sulfite,[1] (2) *R-242*, p-chlorophenyl phenyl sulfone, (3) *923*, 2,4 dichlorophenyl ester benzene sulfonic acid and (4) *K-6451*, p-chlorophenyl p-chlorobenzene sulfonate. Initial spider mite records were made on 50 leaves selected at random on 50 plants in each plat. Later records were made on the same leaves for determining the percentages of reduction. It will be observed that sprays applied by the ground machine were more effective than those applied by airplane. Apparently 3 nozzles per row gives a better distribution or penetration of the spray into the lower part of the plants than sprays applied by plane. The first material proved to be the most toxic of the compounds used. The residual toxicity of *Compound K-6451* was greater than either of the other complunds.

SUMMARY.—Toxaphene, aldrin and dieldrin in both spray and dust formulations were used against thrips in a split-plat randomized block experiment. The sprays proved more effective than the

[1] *Aramite*—Test material No. 1.

dusts. Aldrin and dieldrin sprays, at rates of 0.08 and 0.09 pound per acre, more effective than toxaphene applied at 0.73 pound per acre. Dieldrin showed more residual toxicity than either aldrin or toxaphene.

In another split-plat randomized block experiment, toxaphene, toxaphene-DDT and gamma benzene hexachloride-DDT dusts proved equally effective for boll weevil and bollworm control. The spray formulation of toxaphene-DDT was as effective as the dusts. Toxaphene and gamma benzene hexachloride-DDT sprays were not as effective as the toxaphene-DDT spray nor the toxaphene dust. In laboratory tests, toxaphene-DDT spray proved more effective than toxaphene spray for boll weevil control, particularly at the high levels of kill. The mixing of toxaphene and DDT did not increase the toxicity of the mixture for weevil control over comparable dosages of toxaphene and DDT applied separately.

In a randomized block experiment in which a heavy bollworm injury occurred, toxaphene and 3-5-40 dusts were equally effective and both dusts gave significantly better control than dieldrin dust, dieldrin spray, toxaphene spray or aldrin spray.

In the large plats results comparable to those of the small replicated plats were obtained. The results from the four tests with plats ranging in size from 1 to 40 acres indicate that sprays applied either with a tractor or an airplane were effective for boll weevil and bollworm control. In the tests, 6 to 12 applications were required and average net gains in yields over the check plats ranged from 672 to 1223 pounds of seed cotton per acre, a net profit ranging from $75 to $133 per acre.

A comparison of Test Material #1[1] *Compound R-242*, *Compound 923* and *Compound K-6451* for spider mite control was made using both ground machine and airplanes to apply the sprays. The ground machine applications were more effective than the airplane applications. Test Material #1[1] was more effective than the other sulphur compounds used.

LITERATURE CITED

Dean, H. A. and J. C. Gaines. 1950. Comparison of dusts and sprays for cotton insect control. JOUR. ECON. ENT. **43**(2): 225.

Gaines, J. C., H. A. Dean and Read Wipprecht. 1948. Control of thrips on cotton. JOUR. ECON. ENT. **41**(3): 594.

Gaines, J. C., E. E. Ivy, H. A. Dean and A. L. Scales. 1950. Toxicity of various sulphur and phosphorus compounds applied as sprays on spider mites and aphids. JOUR. ECON. ENT. **43**(5): 614.

Effects of Insecticides on Biological Control of Insect Pests of Citrus[1]

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The advent of DDT and of the powerful new organic insecticides following in its wake has emphasized the detrimental effect that insecticidal treatments may exert upon the natural enemies of pests of orchard crops. Citrus plantings, subjected as they are to a great variety of pest control applications, present perhaps the best and most available picture of the deleterious effects of various chemical control treatments on biological control of insect pests.

Much of the information hitherto obtainable on the effects of insecticidal and fungicidal treatments on natural enemies of citrus pests has been drawn from observational evidence, without quantitative data to correlate natural enemy activity and host densities under field conditions. It is the first concern in investigations of this subject to demonstrate that biotic control exists or can be obtained under field conditions, and to indicate the extent to which each natural enemy species contributes toward this control.

Only comparatively recently, through the use of specific insecticides, has it be-

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come practical to design field experiments which will not only evaluate the effectiveness of the entomophagous insects in a given complex, but also simultaneously show the effect of various other insecticides on host and parasite or predator populations. The powerful new insecticides themselves have supplied investigators with a technique for eliminating certain beneficial species so that their effect upon host density might be separated from the effect of climatic and other factors. DDT, due to its relative innocuousness in some forms to red spiders, scale insects, and mealybugs, and its great toxicity to many hymenopterous parasites and ladybird beetles, has been particularly useful in this regard.

Review of Literature.—Earlier literature on the effects of citrus pest control applications on biological control pertained largely to the results of field observations of obvious upsets in the natural balance in relation to the use of a given insecticide. Literature reporting planned laboratory or field experiments has appeared principally during the past decade.

Smith (1929) pointed out that cottony-cushion scale-infested trees could be sprayed with arsenicals which protected the egg sacks of the scale from vedalia and thereby indirectly demonstrated the effectiveness of the predator. Clausen, in 1936, recorded an instance in Malaya where citrus trees periodically sprayed with kerosene emulsion maintained heavy average populations of citrus blackfly, whereas blackfly populations on comparable untreated trees were reduced by parasitization. These latter trees remained clean over a 2-year period of observation. Boyce (1936) suggested that the increasing citrus red mite problem might well be due to lowered predator populations brought about by increased and continuous acaricidal treatments. Osburn & Spencer (1938) studied the effect of sulfur residues on citrus scale insects and found increased purple scale and Florida red scale populations despite a somewhat toxic effect upon young scale crawlers.

Henderson & McBurnie (1938–1939) have described extensive studies on the effects of common citrus spray materials on natural enemies of yellow scale, citrus red mite, and citrus mealybugs in southern California. This work was continued by Henderson & Holloway (1940–1943) in comprehensive studies on effects of oil sprays, HCN fumigation, tartar emetic, sulfur, and other materials in the field against a great number of parasites and predators. They found that fumigation resulted in lower relative mortality of pupal *Comperiella* than of its host, the yellow scale, whereas oil spray caused nearly the same mortality of parasite and scale. Similar results were obtained with *Metaphycus helvolus* and its host, the black scale. Cryolite dust was definitely detrimental to larval *Cryptolaemus* populations in both laboratory and field tests. In the field sulfur dust was found to be possibly more detrimental than cryolite to *Cryptolaemus*. Sulfur dust likewise killed *Comperiella* adults in the field, especially under conditions of high temperature. Tartar-emetic plus sugar was found in laboratory tests to be toxic for a considerable period to adults of *Lindorus lophanthae*, *Comperiella bifasciata*, *Metaphycus helvolus*, *Leptomastidea abnormis*, and others.

Holloway *et al.*, in 1942, published the results of field studies on effects of insecticidally inert residues on citrus red spider increase. Flanders (1941) re-examined the effects of inert residue on various insect populations, and DeBach (1947, 1949) pointed out the detrimental effects of so-called insecticidally inert materials on certain parasites and predators as being pronounced and sometimes quite specific for different natural enemies.

Ebeling (1945) first noted the increase in populations of citrus red mite and aphids associated with DDT treatment of citrus, and stated that 5 per cent DDT dust actually appeared to have increased populations of California red scale in the field. Possible effects on natural enemies were suggested as an explanation for these conditions. DeBach (1946) reported the successful use of DDT dust as a check method for measuring the effect of natural enemies on pest populations, due to differential effects on hosts and beneficial species. Griffiths & Thompson (1947) pointed out that in some instances when DDT was applied to citrus trees in Florida, populations of Florida red scale, rust mite, citrus mealybug, and citrus red mite increased so drastically as to necessitate advice against DDT application to citrus. Griffiths & Stearns (1947) reported the increase in Florida red scale as being due

to a direct effect of DDT on natural enemy populations.

Griffiths & Fisher (1949) reviewed the effects of residues on pest population increases on citrus trees in Florida and found evidence that trees sprayed with formulations of copper or zinc-lime, or both, had longer periods of high populations of purple scale than did trees receiving the other treatments used. These treatments also appeared to increase populations of the rust mite. The lowest scale increase occurred on the unsprayed controls. These workers showed also that certain residue sprays, especially zinc and lime, reduce the incidence of chytridiosis, a fungus disease of the purple scale.

Woglum *et al.* (1947), on the basis of long-range field observations, concluded that many species of natural enemies of citrus pests in California have been greatly reduced over the years by the increased intensity of insecticidal treatments. Ullyett (1948) reports similar findings in a review of citrus pest control in South Africa.

Additions to the list of reported upsets in the accustomed balance between certain citrus pests and their natural enemies are constantly being encountered. That such changes are directly due to an effect upon natural enemies has not always been proved, but most of such cases are known to be associated with the application of pest control materials, and circumstantial evidence and factual information indicate that adverse effects by the chemicals on natural enemy activity are involved.

Ebeling's (1945) observations with respect to increases in aphid populations on citrus after DDT application have been verified by the authors in connection with studies on citrus red mite and California red scale.

In the present investigations, population increases in citrus mealybug, yellow scale, soft brown scale, and two-spotted mite were all, at certain times, observed to be associated with applications of various formulations of DDT. Observations on the citrus mealybug have been adequate to establish with reasonable certainty the fact that increases in this pest have been associated with inhibition or elimination of predators for considerable periods.

Unpublished data on file in the Division of Entomology of the University of California Citrus Experiment Station at Riverside indicate that some degree of control of orange tortrix was accomplished over a 3-year period by continued DDT-kerosene application, but that when the treatment was discontinued a drastic increase of the tortrix was manifested during the following season. This was attributed to a differential toxicity on the orange tortrix and its *Apanteles* parasite. Other observations have shown abnormal increases in populations of soft brown scale when parathion was applied experimentally for the control of other citrus pests. Soft brown scale is a minor pest normally under satisfactory biological control.

EXPERIMENTATION.—The following experiments concern the effect of insecticides on the cottony cushion scale—vedalia complex, the citrus red mite—predator complex, the long-tailed mealybug —parasite and predator complex, and the California red scale—parasite and predator complex. The quantitative data derived from these specific studies are thought to illustrate some of the general principles involved in insecticidal and biological control relationships.

THE COTTONY-CUSHION SCALE AND ITS PREDATOR, THE VEDALIA.—In numerous citrus groves in the central valley of California, after widespread applications of DDT to citrus and other crops in 1946, cottony cushion scale increased in numbers sufficiently to become a serious pest. A study of the direct and indirect effects of DDT on the cottony-cushion scale vedalia complex was undertaken, since this is perhaps the most striking instance of adverse effects of an insecticide on an entomophagous species that normally holds its host under perfect biological control.

Preliminary laboratory tests were conducted to obtain some indication of the normal residual effectiveness of varied DDT applications with respect to vedalia toxicity. Leaves were brought from the field to the laboratory and placed in petri dishes with adult vedalias of uniform age, supplied with food and water. Tests of residues from late summer sprays indicated that at least two months after application enough DDT remained on the foliage to cause 100 per cent mortality in 24 hours, compared with less than 10 per cent check mortality.

A study of outbreaks of cottony-cushion scale in the field subsequent to DDT applications was conducted over a 2-year period. It was found that in groves where DDT treatment against citrus thrips or citricola scale had been applied prior to July, the residue had weathered sufficiently before fall to permit re-entrance of vedalia and consequent biological control; but in groves treated in the winter or early spring, and again after July, the scale was protected from vedalia attack throughout the entire season. Comparative data from adjacent treated, active- and inactive-residue test plots having a high population density of cottony cushion scale indicated that vedalia populations cleaned up infestations on trees bearing weathered, inactive DDT residues and then migrated en masse to trees bearing active DDT residues, where some few eggs were laid before their death. However, the very few adults that develop from these eggs were killed by residues during their active preoviposition period, without themselves ovipositing. This suggested that a scale-infested grove surrounded by DDT-treated properties might be materially retarded in a cleanup owing to the "trap effects" of DDT-treated areas on migrant adult predators or parasites. Such a "trap effect" was suggested by Flanders (1934) as a possibility with sulfur and the black scale parasite *Metaphycus helvolus*.

This trap effect was demonstrated experimentally in two groves where cottony-cushion scale had built up to serious proportions as the result of previous DDT treatments. At the time of the test the residue had weathered to such an extent that vedalia were expected soon to start moving into the area from outside. In each orchard four trees were selected as test plots and two tree rows surrounding the plot areas were treated with a single application of 2 pounds of 50 per cent wettable DDT per 100 gallons of water, at the rate of 20 gallons per tree. Four untreated trees, 20 tree rows distant in each grove, served as check plots. Data from the two groves were taken over a 6-month period. The results from one grove duplicated those from the other. It was found that a definite trap action was exerted on the untreated areas by neighboring DDT-treated trees. This was exhibited as both a lag in vedalia increase in the untreated area surrounded by DDT-treated trees, and a less thorough reduction of the cottony-cushion scale which would naturally serve as an incipient infestation the following season.

Table 1.—Relative populations of vedalia larvae developed in check plots and in plots treated with DDT, using various schedules and types of treatment, 1947.

Date of Treatment	Vedalia Population After Treatment (Untreated Control = 100)			
	DDT Dust	DDT Spray Dust[1]	DDT Wettable-Powder Spray	DDT Kerosene-Emulsion Spray
April	—	75	15	19
June	100+	100+	4	4
April and June	—	52	0	0

[1] A semiconcentrate spray applied with large-volume airblast equipment.

In 1947 a series of tests using DDT in varied schedules and types of treatment was conducted in two groves having appreciable populations of cottony-cushion scale. The DDT-treated trees were located at random throughout the groves, so that migrant vedalia would be available for reestablishment as soon as DDT residues became nontoxic. The results of these tests are shown in table 1. From the data it is evident that both DDT-wettable and DDT-kerosene deposits were decidedly toxic to adult vedalia. Under such

Table 2.—Effect of various insecticidal treatments on increase or decrease in citrus red mite and combined predator populations (compared with populations in untreated check plots) in four Orange County Valencia orange groves, 1947.[1]

Spray Material	Per Cent Increase (+) or Decrease (−)			
	Citrus Red Mites		All Predator Spp.	
	After One Application	After Three Applications	After One Application	After Three Applications
DDT	+29	+55	−33	−87
Cryolite	+17	+12	+3	−54
Zinc sulfate	+14	+32	−12	−43
Pyrophyllite	−13	−27	−7	−51
Chlordane	−7	−18	+4	−53
K-1875[2]	−24	−84	−36	−94

[1] Calculated from averages of biweekly counts over a 6-month period following first insecticidal application. Second and third applications followed the first at 6-week intervals.

conditions this toxicity persisted for at least 3 months. Toxic effects from spray dust and dust formulations were definitely of much shorter duration than those from complete-coverage sprays.

THE CITRUS RED MITE AND ITS PREDATORS.—The ecology of the citrus red mite is imperfectly understood. Under certain conditions high temperature with low humidity has caused large-scale declines in citrus red mite populations. At other times various predators have been accountably responsible for the decreases. The data that follow are considered primarily from the standpoint of the effect of pest control materials on populations of citrus red mite predators. For simplification, all species of principal predators are grouped together. These include *Stethorus picipes* Casey and *Conwentzia hageni* Banks,[1] which are about equally common, and *Chrysopa californica* Coq., which is somewhat less abundant. *Somatium oviformis* (Casey) is generally rare, and few predatory mites or thrips were recorded during these studies. Several species of polyphagous Coccinellidae such as *Hippodamia, Coccinella, Adalia,* and *Olla* were abundant at times, but were recorded only on a qualitative basis.

Each treatment was applied to three tree replicates within a grove area of more or less uniform mite population density. Treatments included DDT, pyrophyllite, zinc sulfate, cryolite, chlordane, dicyclohexylamine salt of dinitro-o-cyclohexylphenol,[2] and bis-(*p*-chlorophenoxy)-methane.[3] The choice of tree replicates followed preliminary counts, in order to minimize the variation in population density between treatments. Treatments were applied as sprays, the total residue being the same (2 lb. per tree) for all treatments involving solid particles, except *Dinitro 1,* an acaricide. Others were applied in amounts approximating usual commercial or experimental practices, as were the toxic constituents in the treatments involving solid particles. Each different insecticide experiment consisted of plots given one application and plots given three applications. Population census data were obtained at successive 2-week intervals throughout the year. A part of the data illustrative of certain effects of insecticides on mite and predator populations in four groves were averaged for the present discussion and are recorded in table 2. Evaluation of the relative effect of predators, treatments, or climate on citrus red mite populations, would require consideration of census data in detail and from many angles. For present purposes such an analysis is omitted.

From the data in table 2 it is evident that DDT, cryolite, and zinc sulfate applications resulted in substantial increases in mite populations, in comparison with those of untreated checks. These increases are correlated with adverse effects against predators. Effects against predators were emphasized by three applications. Under conditions of these tests the effects of DDT persisted for 2 to 4 months or more. Cryolite plots after one application showed 3 per cent more total predators than the checks, but this actually represents a lower relative predator population density, since mite populations were higher.

Applications of chlordane, pyrophyllite, and *K-1875* resulted in decreased mite populations, in comparison with those of untreated checks. The reasons for these decreases, as well as for the increases associated with the three insecticides discussed above, may be different in connection with each material. *K-1875* of course, is known to be toxic to the citrus red mite. Chlordane also is known to have some acaricidal effect. Pyrophyllite may have resulted in retardation of mite populations as a result of the mechanical effects of application. All affected predator populations adversely, *K-1875* probably by starvation.

To understand why the results shown in table 2 occurred, it is necessary to consider far more than the effect of the various treatments on average total populations of the common mite predators. The relative proportions of total populations of the different predator species vary with the different treatments (Tables 3 and 4), and the chronological development of mite populations and of the different predator species also varies with the different treatments (Fig. 1). In addition, applications of these materials may result in increases of other pests such as mealybugs (page 379) and aphids (Table 6), which, in turn, may subsequently result in

[1] Now known to be a complex including several species.
[2] *DN-111;* The Dow Chemical Company. (Referred to as *Dinitro #1*).
[3] *Neotran;* The Dow Chemical Company. (Referred to as *K-1875*).

Table 3.—Effect of various insecticidal treatments on increase or decrease in populations of common species of predators of citrus red mite (compared with populations in untreated check plots) in four Orange County Valencia orange groves, 1947.[1]

Spray Material	Per Cent Increase (+) or Decrease (−)					
	After One Application			After Three Applications		
	Stethorus	*Conwentzia*	*Chrysopa*	*Stethorus*	*Conwentzia*	*Chrysopa*
DDT	+208	−93	−48	−65	−100	−77
Cryolite	+64	−6	−18	−7	−82	−30
Zinc sulfate	−23	−4	−26	+3	−76	+17
Pyrophyllite	−41	+1	−5	−23	−73	−3
Chlordane	−64	+15	+26	−22	−88	+57
K-1875	−88	−29	+19	−100	−98	−55

[1] Calculated from averages of biweekly counts over a 6-month period following first insecticidal application. Second and third applications followed the first at 6-week intervals.

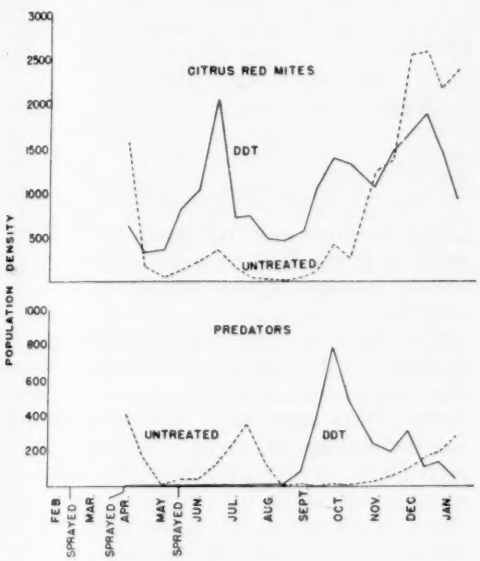

FIG. 1.—Changes in citrus red mite and predator populations following three applications of DDT spray, in 1947.

increases in populations of general predators such as *Chrysopa* (when chlordane is used (Table 3) and various species of coccinellids. Such general predators may account for average mite populations being lower in certain treated plots than in checks. General predators may also be adversely affected by various treatments (Table 5). Many other factors are doubtless involved in the complex interactions that occur on a citrus tree. Obviously, a detailed study would be necessary to explain completely why certain effects on mite populations may follow the use of even one material. For the present, we must be satisfied to consider the most obvious factors.

Table 3 shows the relative increase or decrease of each species of predator in the variously treated plots, as compared with populations of the same species in untreated check plots. After one DDT application, *Stethorus* populations increased markedly, whereas *Conwentzia* decreased, markedly, and *Chrysopa* decreased about half as much. When three applications of DDT were used, even *Stethorus*, which shows considerable tolerance to DDT, was markedly reduced; *Conwentzia* was completely eliminated, and the highest mite populations obtained in any plots resulted. Of interest is the increase shown by *Chrysopa* after applications of chlordane. It is known that the chlordane-treated plots showed the greatest increases in mealybug populations. Apparently, chlordane was not especially ad-

Table 4.—Relative proportions of predator species making up the common citrus red mite-predator complex after various insecticidal treatments in four Orange County Valencia orange groves, 1947.[1]

Predator Species	Untreated Check	Percentage of Predators Surviving Spray Application											
		DDT		Cryolite		Zinc		Pyrophyllite		Chlordane		*K-1875*	
		One	Three	One	Three	One	Three	One	Three	One	Three	One	Three
Stethorus	17	78	82	27	61	15	55	11	48	6	51	4	0
Conwentzia	64	7	0	58	24	69	25	69	32	71	16	80	18
Chrysopa	19	15	18	15	15	16	20	20	20	23	33	16	82

[1] Calculated from averages of biweekly counts made over a 6-month period following first insecticidal applications. Second and third applications followed the first at 6-week intervals.

Table 5.—Percentage of treated trees (compared with untreated trees) having polyphagous coccinellid larvae present during the normal period of aphid infestation, in three Orange County Valencia orange groves, 1947.[1]

Spray Material	After One Application	After Three Applications
DDT	36	6
Cryolite	91	53
Zinc sulfate	77	71
Pyrophyllite	77	76
Chlordane	86	76
Dinitro #1	38	25
Untreated checks	100	100

[1] Calculated from averages of biweekly counts made over a 6-month period following first insecticidal applications. Second and third applications followed the first at 6-week intervals.

verse to *Chrysopa*, and populations of this predator increased in response to the heavier mealybug population.

Table 4 shows the changes in proportion, regardless of increase or decrease in total numbers, of common species of citrus red mite predators following various insecticidal treatments. Even one DDT application radically changed the predator complex from dominantly *Conwentzia* to dominantly *Stethorus*. *Conwentzia* was eliminated by three DDT applications. Except in one case, three applications of material (as compared with one application) resulted in a decided shift of the predator complex toward a greater proportion of *Stethorus* and a smaller proportion of *Conwentzia*. The one exception followed *K-1875* applications, which reduced mite populations below the level at which *Stethorus* could successfully exist. The proportion of *Chrysopa* increased appreciably after three applications of chlordane or *K-1875*. Single applications of cryolite, zinc sulfate, or pyrophyllite did not change the relative proportions of the various species in the complex to any great extent. Single applications of chlordane and *K-1875* resulted in a decrease in the proportion of *Stethorus* present, and a possible increase in the proportion of *Conwentzia*.

In addition to adverse effects on the most common and specific citrus red mite predators, the spray applications had adverse effects on the common polyphagous coccinellids of several species. Table 5 shows that coccinellid larval populations were depressed by every treatment used, and that DDT and *K-1875* produced the most drastic effects. The effects of

Table 6.—Relative frequency of heavier-than-normal aphid infestations on Valencia orange trees given various insecticidal treatments; County Farm Grove, Orange County, 1947.

Spray Material	Number of Applications	Frequency of Aphid Infestations (Maximum Possible, 33)
DDT	1	2
	3	19
Cryolite	3	5
Zinc sulfate	3	3
Pyrophyllite	1	0
	3	0
Chlordane	1	0
	3	0
Dinitro #1	1	0
	3	0
Untreated check	—	0

DDT are from toxicity; those of *K-1875* may be partially owing to a lower food supply because of the toxicity of *K-1875* to mites.

The data in table 6 are included as a further illustration of the many effects that may result from the use of one material. Data were kept concerning aphid infestations in one grove. The 13 randomized plots involved included 6 receiving one application of insecticide, 6 receiving three applications of insecticide, and 1 untreated. Of the 13 plots, 4 showed heavy aphid infestations at times; the other 9 plots, including the untreated check, showed none. Three applications of DDT produced the heaviest aphid infestations, three applications of cryolite resulted in about one fourth as many aphids, whereas three applications of zinc sulfate or one application of DDT produced somewhat fewer. The DDT single-application plot was the only one that showed aphid infestations. It is of interest that, aside from the *Dinitro #2* treated plot, these same four plots showed the greatest depressions of coccinellid larvae.

It should be recognized that effects against predators were minimized in these studies because the treated trees were surrounded by untreated trees from which constant immigration of predators could occur. Treatment of large areas would be

Table 7.—Comparative effect of DDT and talc residues on predator populations and percentage parasitization of the long-tailed mealybug, per tree-trunk-band sample, following experimental treatment, March, 1946.

Monthly Count	Number of Predators			Per Cent Parasitization		
	DDT-Treated	Talc-Treated	Untreated (Check)	DDT-Treated	Talc-Treated	Untreated (Check)
March[1]	1	1	1	13	13	13
April	0	4	4	17	12	18
May	0	3	34	33	18	14
June	5	32	21	44	21	17
July	10	37	29	64	38	23
August	6	5	5	79	44	38
September	1	3	2	70	30	26

[1] Pre-treatment count.

expected to result in a much more adverse effect against predators.

Although data may be grouped, as in tables 2 to 6, to present a general picture in its simplest terms, this procedure may obscure important details, especially those necessary for an understanding of the dynamics of the interacting populations. The curves of figure 1 show some detailed census data obtained from the field. This particular illustration constitutes a comparison between a check plot and a plot receiving three applications of DDT during the first half of 1947. Aside from any consideration of the effectiveness of the predators, it is readily apparent that the three DDT treatments virtually eliminated predators for a period of about 6 months, during which time the red mite population became, and remained, much higher than on the check plot. Approximately 3 months after the last DDT treatment, predators again became established on the DDT trees and proceeded to build up, although, as shown in tables 3 and 4, the complex of predator species was different from that on the untreated trees. *Stethorus* definitely is less affected by DDT than *Conwentzia*, and therefore becomes re-established sooner after treatment.

The Long-Tailed Mealybug and Its Parasites and Predators.—The long-tailed mealybug attained the status of a minor pest on citrus for the first time in 1933. Since then, the infested area has considerably expanded. Studies undertaken in 1946 to determine the status of the various natural enemies of this mealybug led to the accumulation of experimental data concerning the effect of DDT and talc on the predator-parasite complex. These data, in part, as well as the methods and formulations used, have previously been discussed (DeBach 1946, 1949).

Monthly counts were made of the number of predators and the percentage of parasitization per corrugated tree-trunk-band sample in three Orange County groves. Mealybug population figures are not included, because, in the present case, their consideration does not greatly influence the relationships obtained. Data are included only through September, 1946, since populations all became too low for comparisons after that date.

The data in table 7 indicate that DDT, as used, had no adverse effect on populations of parasites of the long-tailed mealybug, but did effectively reduce predator populations over a considerable period. Talc, used for comparison with DDT from a standpoint of residue, also was detrimental to predator populations, and it inhibited increase of the predators for about one month after they began to be abundant on adjacent untreated trees.

Parasitization became higher on the DDT-treated trees than on untreated trees in any other grove observed, apparently for the following reasons: *Anarhopus syndeyensis* Timb., the principal parasite of the long-tailed mealybug, was relatively unaffected by DDT; predator competition was virtually eliminated; and *Lygocerus*, a common hyperparasite of *Anarhopus*, was selectively eliminated by DDT, as was *Tetracnemus pretiosus* Timb. the second most important parasite of the long-tailed mealybug. Thus *Anarhopus* was suddenly released from a major portion of its biological competition.

The selective effect of DDT on percent-

age parasitization of the long-tailed mealybug by *Anarhopus* and its hyperparasite *Lygocerus* is shown in figure 2. The effect of DDT on parasitization by *Tetracnemus pretiosus* is shown in figure 3.

Exploratory studies similar to those discussed in the previous section on the citrus red mite and its predators were conducted during 1947 to determine the effect of DDT, pyrophyllite, chlordane, cryolite, zinc sulfate, *Dinitro #1* and *K-1875* and oil on natural enemies of the long-tailed mealybug.

Periodic census data show that under conditions of the experiment chlordane, cryolite, zinc sulfate, and *K-1875* in the order named, tend to cause some increase in mealybug populations over checks. DDT used as a heavy, complete-coverage spray in these tests caused definite reductions in populations of long-tailed mealybugs, which did not tend to "flare" back.

THE CALIFORNIA RED SCALE AND ITS PARASITES AND PREDATORS.—Previous work by DeBach *et al.* (1951) has revealed that under certain favorable circumstances California red scale populations are regulated at low densities by action of the parasite *Aphytis chrysomphali* (Mercet), but under environmental conditions unfavorable to *Aphytis* are regulated at higher density levels by a group of ladybird beetles consisting primarily of *Lindorus lophanthae* (Blaisd.), *Chilocorus stigma* (Say), and *Orcus chalybeus* (Boisd.). A number of vigorous and productive citrus groves distributed more or less randomly in southern California have avoided chemical control treatment of or red scale for periods up to 10 or more years by virtue of the attainment of a balance between the red scale and its natural enemies. This occurs despite the proven suitability of climate and host plant for the California red scale. It appears, then that even though the entomophagous species involved have not been ordinarily considered highly efficient, nevertheless, in the absence of unusual environmental resistance factors, these natural enemies can attain and maintain a balance unfavorable to the economic abundance of red scale.

Certain citrus groves adjoining these biological control groves and maintained under similar cultural conditions received annual oil-spray treatments or HCN fumigation. A study of these treated groves poses the question as to whether or not annual chemical control treatments can sufficiently upset host-parasite relationships to prove disastrous to the maintenance of biological control of red scale. The extent to which periodic chemical control treatment may disrupt the influence of beneficial insects in controlling California red scale is a matter difficult to determine without a very long-range program, since effects may be accretive from one year to the next. It is obvious, however, that if drastic reductions in red scale populations are caused periodically by insecticidal treatments, severe upsets in the normal population dynamics of the

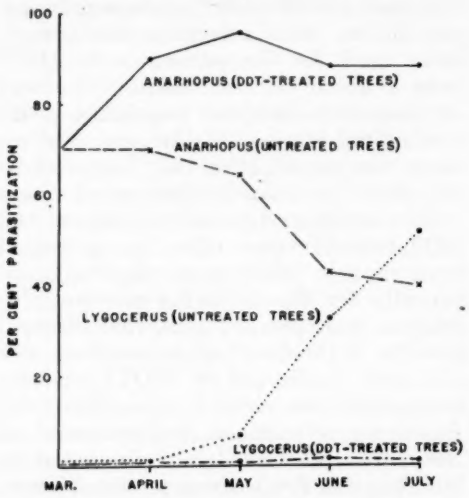

FIG. 2.—Effect of DDT on percentage of parasitization of the long-tailed mealybug by the primary parasite *Anarhopus sydneyensis* Timberlake and the hyperparasite *Lygocerus* sp. (Trees treated March, 1946.)

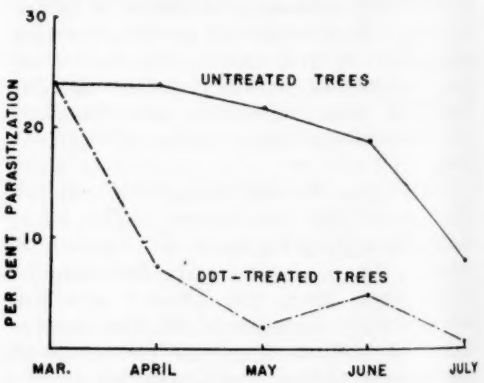

FIG. 3.—Effect of DDT on percentage of parasitization of the long-tailed mealybug by *Tetracnemus pretiosus* Timberlake. (Trees treated March, 1946.)

red scale and its natural enemies will occur.

From a short-range standpoint, certain evidence supports the belief that biological control of red scale might be upset very easily by certain chemical control practices. A test was designed to demonstrate what might be expected to occur under conditions of known biological control of red scale when an insecticide having a long residual effect was applied to citrus for purposes other than red scale control.

For purposes of the test, two biological control groves in Santa Barbara County were chosen, wherein natural enemies could be kept from lemon trees by the monthly application of a light dosage of DDT, somewhat similar to that in use in central California for control of citrus thrips. The treatment consisted of monthly spraying of the plot trees with 1 to 2 quarts per tree of a suspension of 4 pounds of 50 per cent wettable DDT per 100 gallons of water, using a knapsack sprayer. This dosage does not inhibit increase in red scale population, but is extremely toxic to parasites and predators In the same series of comparative experiments, Argentine ants, which were fairly common in the groves under consideration, were kept off a group of trees by treatment of the soil around the trunk with 5 per cent chlordane dust. The adverse effect of the Argentine ant on the biological control activity of *Aphytis* against red scale has been pointed out by DeBach *et al.* (1951).

Comparative scale population counts were taken over a period of one and a half years after inauguration of the test. Count values used were the average number of scales found upon random samples of 24 3-inch twig terminals from each tree in each plot. Average scale counts per tree are presented in table 8. Results indicate an excellent degree of biological control existent in the two groves, and demonstrate the severe disruption of host-parasite balance produced by continuous, monthly light treatment with DDT. Argentine ants produced a similar but less drastic effect on natural enemies. These data serve to emphasize the danger involved in application of a residue-retentive insecticide to citrus trees on which red scale and its natural enemies occur in a favorable state of balance.

Table 8.—Relative California red scale population densities in biological control plots and in plots in which parasite activity had been suppressed by prior, monthly applications of a light DDT spray or by Argentine ants; January, 1950.

Grove No.	Average Red Scale Population Density		
	Biological Control Plots[1]	DDT-Sprayed Plots[2]	Ant-infested Plots[3]
1	3	425	65
2	16	575	145

[1] Ants controlled by 18 prior monthly applications of chlordane to soil.
[2] Parasite activity suppressed by 11 prior monthly applications of DDT spray to foliage.
[3] Parasite activity suppressed by normal presence of ants.

In connection with the above results it is interesting to note that as far back as 1929 Clark & Friend (1932), working with California red scale, then the worst citrus pest in the lower Rio Grande Valley of Texas, made monthly applications of lime-sulfur solution to citrus trees and produced an extraordinary increase of red scale over that on unsprayed trees. These authors ascribed the increase to the repellent action of lime-sulfur to parasites and predators of the scale, although at that time natural enemies were not credited with being able to control California red scale populations successfully.

Discussion.—From a study of previous literature and the results of the laboratory and field studies herein presented, certain principal features of the complex relationship between citrus pest populations, their natural enemies, and chemical pest control treatments are indicated.

Adverse effects of chemical control treatments on natural enemy populations may be produced in three ways: first, through direct toxicity to entomophagous or entomogenous species; secondly, through toxicity or repellent action of pest control treatments ordinarily considered insecticidally inert; and thirdly, through more or less complete elimination of beneficial species by starvation following drastic reductions of host populations by pest control treatment. Natural enemy density changes resulting from host reduction and consequent starvation may be so severe as to result in oscillations of pest density that produce greater crop damage than would ordinarily occur in the absence of treatment. Such flare-ups or extreme oscilla-

tions may therefore serve as good indicators of an upset natural balance between the pest and its natural enemies.

Any upsets in the natural balance established between a host and natural enemies, caused by detrimental effects of insecticides, may be sudden but more or less transient upsets of the balance, or may be slow but permanent upsets resulting from accumulative effects of smaller increments over long periods of time, where fixed pest control schedules are employed. In this connection it appears possible that, as Boyce (1936) has pointed out for citrus red mite, such pest control programs as oil spray and HCN fumigation for California red scale could operate over a period of years, through elimination of host material at critical periods, to cause starvation and near elimination of natural enemies, and thus result in an accumulating advantage to the host and disadvantage to the beneficial species.

Although considerable investigation of many features of the complex relationship between insecticides and natural enemies and pest populations is desirable, three lines of investigation stand out as offering particularly promising possibilities: (1) determination of the degree of biological control attainable in the complete absence of treatment, (2) manipulation of pest control treatment so as to conserve natural enemy reservoirs, and (3) determination of the specificity of various chemical control materials to particular species of natural enemies.

The first line of attack listed above, a determination of the complete potential effectiveness of the natural enemies in the absence of treatment, is essential and fundamental to any attempt to determine the effect of insecticides on natural enemy and pest populations. An evaluation of the possible detrimental effects of insecticides cannot be made unless the full potentialities of the natural enemies are known. In this regard it must be borne in mind that a grove newly out of treatment cannot be considered an untreated grove for purposes of evaluation of the potential effectiveness of natural enemies. Population trends of both natural enemy and host may be affected for periods much longer than that during which the insecticide persists, because a more or less extended period may be necessary to re-establish normal balance or equilibrium. In California-red-scale-infested areas favorable to the activity of the parasite *Aphytis*, indications are that, after the application of an oil spray for red scale, 3 to 5 years may pass before a satisfactory balance is regained.

Another important consideration in attempts to evaluate the potential effectiveness of natural enemies is the choosing of an untreated grove or plot that will not be influenced by the "trap effect" of a surrounding treated area.

Investigations concerning the specificity of various insecticides to particular species of natural enemies and their hosts are extremely important, not only from the standpoint of obtaining the least injurious insecticide for use in any given pest-natural enemy complex, but also in making available materials suitable for use in the insecticidal check method.

SUMMARY.—Literature on the subject of inter-relationships between insecticidal and biological control of citrus pests is reviewed.

Chemical pest control treatments applied to citrus trees against specific pests have resulted in increases of pests such as aphis, citrus mealybug, yellow scale, soft brown scale, two-spotted mite, orange tortrix, cottony-cushion scale, citrus red mite, long-tailed mealybug, and California red scale.

Designed tests with DDT or any material having marked preferential toxicity to natural enemies over their host may be utilized as check methods for determining the relative efficiency of biotic factors, as compared with abiotic factors, in accounting for changes in host population density.

Increases in cottony-cushion scale after DDT treatment have been shown to be caused by a differential toxicity to the scale and its predator vedalia. The "trap effect" of a DDT-treated area on an adjoining untreated area in decreasing the effectiveness of vedalia against cottony-cushion scale has been demonstrated.

Increases in citrus red mite after applications of DDT, cryolite, and zinc sulfate have been shown to be related to the deleterious effects of these materials upon predators. The consequent changes in proportions of species of polyphagous predators have been examined in relation to their interactions with citrus red mite and alternate host species. Specificity of

various insecticides to citrus red mite predators has been shown, with change-overs in dominance of species of the natural-enemy complex resulting from DDT treatments.

Increases in populations of long-tailed mealybug were prompted by applications of chlordane, cryolite, zinc sulfate, bis-(c-chlorophenoxy)-methane(K-1875) talc, and light dosages of DDT. Studies of the effect of DDT and talc on natural enemies showed these materials to be deleterious. The principal primary parasite of the long-tailed mealybug was relatively unaffected by light dosages of DDT, while its principal hyperparasite and the predators of the long-tailed mealybug were selectively eliminated. DDT used at higher dosages destroyed sufficient host material to offset the selective advantage of the host over the natural enemies as demonstrated for lower dosages.

The upset of natural control of California red scale was experimentally demonstrated where a selective advantage was given the host over the parasite by light DDT dosages. A similar selective advantage to the host scale was demonstrated through elimination of parasites by Argentine ant activity.

The danger of certain so-called inert residues and of insecticidal measures which have selective toxicity to natural enemies over that of the host insect have been demonstrated. Host-density changes producing conditions of unnatural balance are discussed. The effectiveness of natural enemies in the absence of treatment, and the long-range effects of insecticidal treatment on beneficial insects, are discussed.

Literature Cited

Boyce, A. M. 1936. The citrus red mite *Paratetranychus citri* McG. in California, and its control. Jour. Econ. Ent. **29**(1): 125–30.

Clark, S. W., and W. H. Friend. 1932. California red scale and its control in the lower Rio Grande Valley of Texas. Texas Agr. Expt. Sta. Bul. **455**: 1–35.

Clausen, C. P. 1936. Insect parasitism and biological control. Ent. Soc. Amer. Ann. **29**(2): 201–23.

DeBach, Paul. 1946. An insecticidal check method for measuring the efficacy of entomophagous insects. Jour. Econ. Ent. **39**(6): 695–7.

DeBach, Paul. 1947. Predators, DDT, and citrus red mite populations. Jour. Econ. Ent. **40**(4): 598–9.

DeBach, Paul. 1949. Population studies of the long-tailed mealybug and its natural enemies on citrus trees in southern California, 1946. Ecology **30**(1): 14–25.

DeBach, Paul. C. A. Fleschner, and E. J. Dietrick. 1951. Natural control of the California red scale in untreated citrus orchards in southern California. Roy. Soc. New Zeal. Proc. Seventh Pacific Sci. Cong. (1949) **4**: (In press.)

Ebeling, Walter. 1945. DDT and rotenone used in oil to control the California red scale. Jour. Econ. Ent. **38**(5): 556–63.

Flanders, S. E. 1941. Dust as an inhibiting factor in the reproduction of insects. Jour. Econ. Ent. **34**(3): 470–1.

Flanders, S. E. 1934. The susceptibility of parasitic Hymenoptera to sulfur. Jour. Econ. Ent. **36**(3): 469.

Griffiths, J. T., Jr., and F. E. Fisher. 1949. Residues on citrus trees in Florida. Jour. Econ. Ent. **42**(5): 829–33.

Griffiths, J. T., Jr., and C. R. Stearns. 1947. A further account of the effects of DDT when used on citrus trees in Florida. Florida Ent. **30**(1, 2): 1–8.

Griffiths, J. T., Jr., and W. L. Thompson. 1947. The use of DDT on citrus trees in Florida. Jour. Econ. Ent. **40**(3): 386–8.

Holloway, J. K., Chas. F. Henderson, and Horace V. McBurnie. 1942. Population increase of citrus red mite associated with the use of sprays containing inert granular residues. Jour. Econ. Ent. **35**(3): 348–50.

Osburn, Max R., and Herbert Spencer. 1938. Effect of spray residues on scale insect populations. Jour. Econ. Ent. **31**(6): 731–2.

Smith, Harry S. 1929. The utilization of entomophagous insects in the control of citrus pests. Fourth Internatl. Cong. Ent. Trans. II: 191–8.

Ullyett, G. C. 1948. Insecticide programs and biological control in South Africa. Jour. Econ. Ent. **41**(2): 337–9.

Woglum, R. S., J. R. LaFollette, W. E. Landon, and H. C. Lewis. 1947. The effect of field-applied insecticides on beneficial insects of citrus in California. Jour. Econ. Ent. **40**(6): 818–20.

Methyl Bromide Fumigation of Walnuts to Control Two Lepidopterous Pests, and Determination of Bromine Residue in Walnut Meats[1]

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The navel orangeworm, *Myelois venipars* Dyar, and the Mediterranean flour moth, *Ephestia kuhniella* Zeller, are serious pests of walnuts in southern California. The navel orangeworm infests the nuts in the field and is brought into the packing house at harvest time, but it has not been shown that this insect will continue to reproduce and maintain itself in the packing house. The Mediterranean flour moth, on the other hand, is chiefly a pest of the stored nuts in the packing house.

Two problems were involved in the fumigation of walnuts for these two pests, namely, fumigation of the nuts on arrival at the packing house to kill the navel orangeworm infestation, and fumigation of the cellophane-packaged nuts in cartons to kill the Mediterranean flour moth. In tests with a series of fumigants such as propylene oxide, ethylene oxide, ethylene dibromide, ethylene dichloride, ethyl formate, methyl formate, isopropyl formate, methyl bromide, acrylonitrile, and various mixtures of these fumigants, it was found that methyl bromide was one of the most effective and practical for use against the two insects in walnuts. The present paper reports the investigation made with methyl bromide. Unless otherwise stated, all fumigations were conducted by the Division of Entomology at the University of California Citrus Experiment Station at Riverside.

MATERIALS AND METHODS.—For fumigation tests with the navel orangeworm, 20 larvae in the fourth and fifth instar were placed in cylindrical wire screen cages. In one series of tests cloth sacks were used, each containing 2 pounds of walnuts. The caged larvae were placed in the center of each sack, the top of which was then drawn together and secured with twine. In the second series of tests double-walled cellophane bags were used, each containing 1 pound of walnuts. The caged larvae were placed in the center of each bag, and the top of the bag was then folded over and sealed with heat.

For laboratory fumigation tests with the Mediterranean flour moth, 25 larvae in the fourth and fifth instar were caged as described above. For each fumigation two double-walled cellophane bags were used, each containing 1 pound of walnuts. The caged larvae were placed in the center of each bag. The tops of both bags were then folded over and heat-sealed, and the bottom of one bag was resealed with heat to preclude the possibility of there being some small leakage at that end.

All laboratory fumigations were conducted in 100-cubic-foot fumigation chambers. Navel orangeworm larvae were fumigated at atmospheric pressure and at a temperature of 65° F. Mediterranean flour moth larvae were fumigated both at atmospheric pressure and at vacuum, at a temperature of 55° F. Circulation of the gas was maintained by a 12-inch fan.

For fumigation of the navel orangeworm, methyl bromide was used at dosages of 2, 3, and 4 pounds per 1000 cubic feet, with exposures of 2, 4, 6, and 8 hours at each dosage. For the Mediterranean flour moth larvae, the dosages ranged from 1 to 12 pounds per 1000 cubic feet, at increasing increments of 2 pounds from 2 to 12 pounds; at each dosage three exposures of 1, 2, and 3 hours were employed.

After the cellophane bags containing the Mediterranean flour moth larvae were fumigated, they were held at 60° to 65° F. for 3 days. The cages of larvae were then taken out of the bags, and the larvae were placed in petri dishes and checked for mortality. They were held 3 days longer to determine whether any larvae which appeared to be dead at the first count might possibly revive, or whether others which were alive might

[1] Paper No. 664, University of California Citrus Experiment Station, Riverside, California.

[2] The authors wish to express their appreciation to the California Walnut Growers Association for supplying the walnuts used in these experiments; to L. E. Vincent, of the Division of Entomology of the University of California Citrus Experiment Station, for assistance in running the fumigations; and to Paul Crandall, of the Division of Plant Physiology, for bromine residue analyses.

Table 1.—**Mortality of larvae of the navel orangeworm fumigated in cloth sacks and in cellophane bags of whole walnuts with methyl bromide at atmospheric pressure; temperature, 65° F.**

Dosage (Pounds per 1000 Cubic Feet)	Exposure Period (Hours)	Per Cent Mortality in—	
		Cloth Sacks	Sealed Cellophane Bags
2	2	100	24.1
2	4	100	45.2
2	6	100	16.7
2	8	100	7.2
3	2	100	23.8
3	4	100	41.0
3	6	100	13.3
3	8	100	89.5
4	2	100	14.3
Control	0	0	—
	0	0	—

die. The cages of larvae used in the navel orangeworm tests were treated in a like manner.

FUMIGATION OF NAVEL ORANGEWORM LARVAE AT ATMOSPHERIC PRESSURE.—Since fumigation for navel orangeworm larvae at the walnut packing houses had to be conducted under atmospheric pressure in practically all instances, experiments were conducted under similar conditions in the laboratory. Because there was also the possibility that some of the nuts might require fumigation in cellophane bags, a number of fumigations were run to determine whether the larvae could be killed in such bags, as well as in cloth sacks.

Results of these tests are presented in table 1. It will be noted that when the navel orangeworm larvae were fumigated

Table 2.—**Mortality of Mediterranean flour moth larvae in heat-sealed cellophane bags of whole walnuts fumigated with methyl bromide at atmospheric pressure and at 25-inch vacuum (released or sustained); temperature, 55° F.**

Dosage (Pounds per 1000 Cubic Feet)	Exposure Period (Hours)	Per Cent Mortality at—					
		Atmospheric Pressure		Released Vacuum[1]		Sustained Vacuum[2]	
		Top of Bag Sealed	Top and Bottom of Bag Sealed	Top of Bag Sealed	Top and Bottom of Bag Sealed	Top of Bag Sealed	Top and Bottom of Bag Sealed
1	1	—	—	91	32	—	—
	2	—	—	68	72	—	—
	3	—	—	84	100	—	—
2	1	7.6	16.0	100	100	100	100
	2	8.0	32.0	100	100	100	100
	3	40.0	32.0	100	100	100	100
4	1	0.0	8.0	100	100	100	100
	2	20.0	12.0	100	100	100	100
	3	16.0	16.0	100	100	100	100
6	1	0.0	0.0	100	100	100	100
	2	4.0	20.8	100	100	100	100
	3	8.0	8.3	100	100	100	100
8	1	36.0	28.0	100	100	100	100
	2	20.0	24.0	100	100	100	100
	3	64.0	68.0	100	100	100	100
10	1	0.0	7.6	100	100	100	100
	2	4.0	4.0	100	100	100	100
	3	4.5	40.0	100	100	100	100
12	1	9.5	12.5	100	100	100	100
	2	28.0	4.0	100	100	100	100
	3	32.0	12.0	100	100	100	100
Control	0	0.0	0.0	8.0	28.6	—	—
	0	4.0	—	—	—	—	—

[1] Vacuum released slowly over a 5-minute period after fumigant was introduced into fumatorium.
[2] Fumigant introduced into fumatorium, and slightly decreased vaccum maintained for remainder of fumigation period.

in loosely woven cloth sacks, 100 per cent mortality was obtained at all dosages and exposures. Fumigation of these larvae in sealed cellophane bags of walnuts at a dosage of 2 pounds of methyl bromide per 1000 cubic feet, in general gave poor kill regardless of the length of the exposure period. At this dosage an exposure of 4 hours gave 45.2 per cent mortality, and an exposure of 8 hours gave only 7.2 per cent mortality. The variability of these results indicates that the cellophane bags probably were not sealed completely. Dosages of 3 and 4 pounds of methyl bromide per 1000 cubic feet gave a very inadequate mortality. This indicates that at atmospheric pressure and exposures of 2 to 6 hours, insufficient quantities of methyl bromide penetrated the cellophane bags to give satisfactory control.

MEDITERRANEAN FLOUR MOTH LARVAE.—*Fumigation at Atmospheric Pressure.*—The purpose of this series of tests was to determine the possible mortality of larvae of the Mediterranean flour moth under fumigation at atmospheric pressure. Results are presented in table 2.

In general, the lowest mortality was obtained with the 1-hour exposure, the 2- and 3-hour exposures showing increasing mortality. Results were somewhat erratic, however. This may be attributed to imperfect sealing or, possibly, to some other, unrecognized imperfections in the cellophane bags, which would allow only enough gas to diffuse inside to kill part of the larvae. These results also indicate that there is a slow diffusion of gas into the cellophane bag, but that it is not rapid enough to build up an adequate concentration to cause complete mortality.

With fumigation at atmospheric pressure, the highest mortality obtained was 68 per cent, and this resulted from a 3-hour exposure to a dosage of 8 pounds of methyl bromide per 1000 cubic feet. Hence, it is evident that the gas did not penetrate the cellophane bags in sufficient quantity to cause mortality commensurate with the amount of gas used. Because results of fumigation at atmospheric pressure were consistently poor at the exposures and dosages tried, it would not be an acceptable method for fumigating cellophane-packaged walnuts.

Vacuum-Fumigation.—In the first series of vacuum fumigations, a vacuum of 25 inches was produced, the methyl bromide was introduced, and the vacuum was released slowly over a period of 5 minutes. This type of fumigation is referred to hereafter as "released vacuum." The results of these tests are presented in table 2.

In the second series of fumigations a sustained vacuum was used. A vacuum of 25 inches was produced, the methyl bromide was introduced, and a slightly decreased vacuum was then maintained for the remainder of the fumigation period The dosages and exposure periods for each dosage were the same as those used in the first series, except that the 1-pound dosage was omitted. Results of these tests are presented in table 2.

From the data in table 2 it is evident that survivors occurred at the 1-pound dosage of methyl bromide per 1000 cubic feet, at exposures of 1, 2, and 3 hours, with released vacuum. No survivors occurred at the 2-pound dosage at an exposure of 1 hour, with either sustained or released vacuum.

Other vacuum fumigation tests were conducted at the Vernon plant of the California Walnut Growers Association in Los Angeles. A cage containing 25 larvae was placed in each of fifteen 1-pound cellophane bags of walnuts, and the bags were sealed by the standard packaging machinery. Three of the bags were held as controls; the other 12 were placed in cartons of packaged nuts at different locations in the fumigation chambers at the Vernon plant. The bags were then fumigated according to the Association's procedure, at a dosage of 2 pounds of methyl bromide per 700 cubic feet for 90 minutes under vacuum. In the procedure followed by the Association, a vacuum of 15 inches is first produced in the chamber; this is held for 10 minutes. The vacuum is then increased to 28 inches, the methyl bromide is introduced, and the slightly reduced vacuum is maintained for 90 minutes. At the end of this exposure the vacuum is released slowly over a period of 10 minutes. The results of these tests showed that 100 per cent mortality was obtained in all instances, regardless of the location of the larvae in the chamber during the fumigation. Natural mortality in the three controls that were run in connection with these tests ranged from

12.5 to 32.0 per cent and averaged 21.8 per cent.

BROMINE RESIDUE IN FUMIGATED WALNUTS.—Because walnut meats contain considerable amounts of oil, and methyl bromide is readily absorbed by fats and oils, it was thought advisable to run analyses to determine the amount of bromine absorbed by the nuts. The walnut meats used in the fumigations were of three sizes classified commercially as "pills" (eighths or smaller), "pieces" (quarters and broken halves), and "halves" (whole halves).

Method.—The method used in these tests was essentially that described by Dudley (1939). A handful of nut meats was taken from each of five fumigated 5-pound cartons of shelled walnuts. The nut meats were mixed, and a 50-gram sample was weighed to the nearest tenth of a gram. "Pills" and "pieces" were used as found; "halves" were coarsely broken.

The samples were placed in Erlenmeyer flasks and were covered with a 1 per cent solution of KOH in 95 per cent alcohol and allowed to stand overnight or longer. They were then transferred to porcelain evaporating dishes of 300-ml. capacity, and the flasks were rinsed twice with small portions of water and once with alcohol. The samples were evaporated to dryness on a steam bath and were then placed in a muffle furnace at 500°–550° C. until dense smoke was no longer given off (about 20 minutes). The dishes were then removed from the furnace and cooled. After the char had been broken up somewhat with a spatula or pestle, it was thoroughly moistened with water, evaporated to dryness over a low gas flame, and returned to the muffle for 2 or 3 hours for ashing. The dish was cooled and the ash was taken up with about 50 ml. of hot water and poured onto a wet filter paper (Whatman No. 40, 12.5 cm.), the filtrate being received in a large porcelain evaporating dish.

The ash was washed once with hot water and poured onto the filter paper. The paper and the wet ash were placed in the dish, and returned to the furnace for about half an hour. After cooling the dish and its contents to room temperature, 4 to 5 ml. of 2 *N* H_2SO_4 was added to the ash to dissolve the carbonates. The mixture was poured onto a wet filter paper and rinsed with one or two small portions of cold water, the filtrate being received in the dish containing the first filtrate and the residue discarded. The combined filtrates were evaporated to dryness on the steam bath. (The first filtrate may be evaporated while the sample is being burned the second time.) The combined filtrate must still be strongly alkaline; if it is not, a small piece or pellet of solid KOH should be added.

After drying, the dish and its contents were cooled, and 25 ml. of H_2SO_4 (1400 ml. H_2O+650 ml. conc. H_2SO_4) was added. The mixture was transferred to a gas-washing bottle, and the dish was rinsed with about 25 ml. of water. Twenty five milliliters of chromic acid reagent (1400 ml. H_2O+200 grams CrO_3+600 ml. conc. H_2SO_4) was then added. Two receivers were used, each containing 50 ml. of 2 per cent KI solution. The system was attached to the suction line and air was bubbled through for 25 minutes. The two receivers were washed into a 500-ml. Erlenmeyer flask, 2 ml. of concentrated HCl was added, and the liberated iodine was titrated with 0.01 *N* $Na_2S_2O_3$, using soluble starch solution as indicator.

Results.—Table 3 gives the concentration of methyl bromide found in 1-pound cellophane bags of whole walnuts which had been subjected to a 25-inch vacuum before introduction of the methyl bromide. It will be noted that after 7 days the cellophane bags contained 0.30 to 0.61 mg. methyl bromide per liter. In that the cellophane bags retain the gas for at least a week after fumigation, they act as small fumigation chambers.

In table 4 are shown the results of analyses for bromine residues in meats of whole walnuts in sealed double-walled cellophane bags exposed to vacuum

Table 3.—Methyl bromide concentration in 1-pound sealed cellophane bags of whole walnuts fumigated with 2 pounds methyl bromide per 1000 cubic feet; 30-minute exposure at 25-inch vacuum.

Test No.	Methyl Bromide Concentration (Mg./Liter) After—					
	1 Hour	24 Hours	48 Hours	7 Days	14 Days	21 Days
4	2.52	1.89	—	0.61	0	0
5	2.37	2.51	1.52	0.31	0	0
6	1.82	1.86	0.68[1]	0.30	0	0

[1] After 4 days.

Table 4.—Bromine residue in meats of whole walnuts vacuum-fumigated in double-walled cellophane bags with 2 pounds of methyl bromide per 1000 cubic feet; 30-minute exposure.

Test No.	Bromine Residue (Mg./100 Gm. Fresh Weight) After—						
	1 Hour	24 Hours	48 Hours	7 Days	14 Days	21 Days	28 Days
1	0.55	2.32	3.03	4.43	5.10	—	—
2	0.42	1.51	3.57	4.53	3.77	—	—
3	0.46	1.67	2.45	4.44	2.85	—	—
4	0.37	1.75	2.72	3.40	3.34	5.19	4.41
5	0.46	2.36	3.34	4.94	4.94	4.33	5.68
6	0.21	1.81	2.91	4.03	4.19	5.01	4.07
Average	0.41	1.90	3.00	4.29	4.03	4.84	4.72

fumigation with 2 pounds methyl bromide per 1000 cubic feet for 30 minutes. One hour after fumigation the nut meats had taken up an average of 0.41 mg. of bromine per 100 grams fresh weight, while those that had been held 21 days in the cellophane bag before sampling had taken up, on the average, as much as 4.84 mg. of bromine per 100 grams fresh weight. This indicates that walnuts sealed in cellophane bags and subjected to fumigation with methyl bromide continue to absorb bromine for at least 3 weeks after the fumigation.

The different sizes of walnut meats are packed in 5-pound cardboard cartons sealed only by staples. Five cartons of pill-sized nut meats were sampled at periods of 15 minutes up to and including 5 weeks after fumigation, as shown in table 5. Five other cartons fumigated at the same time were not sampled until 24 hours after fumigation; they were then sampled up to and including 5 weeks after fumigation. The bromine content of the nut meats remained high during the first hour after fumigation, giving as much as 15.06 mg. bromine/100 grams fresh weight. Within 24 hours after fumigation the bromine content of the nuts had dropped to 7.44 mg. bromine/100 grams fresh weight. This indicates that considerable bromine is taken up by the nut meats during fumigation and is retained by them for the first few hours. After that the bromine is either changed or released until it reaches a rather constant level after 48 hours.

Values are also reported for bromine residue determined on samples of walnut meats lacking the addition of alcoholic KOH previous to the ashing process (Table 5). Since KOH serves to bind all the bromine in inorganic form, the values obtained without the addition of KOH give an estimate of the quantity

Table 5.—Bromine residue in walnut meats ("pills," "pieces," and "halves") fumigated under vacuum with 2.86 pounds methyl bromide per 1000 cubic feet; 90-minute exposure.

Period After Fumigation	Bromine Residue (Mg./100 Gm. Fresh Weight)						
	"Pills"[1]					"Halves"	
	Test No. 1		Test No. 2[2]				
	Total	Without KOH	Total	Without KOH	"Pieces"	Test No. 1	Test No. 2
None (control)	—	—	—	—	0.289	0.266	0.365
15 minutes	14.48	5.75	—	—	13.60	15.05	12.10
1 hour	15.06	4.38	—	—	11.70	12.97	10.41
24 hours	7.44	3.78	6.00	3.25	5.39	5.85	5.55
48 hours	4.44	2.90	5.00	2.53	5.15	4.25	4.68
72 hours	4.22	2.74	4.68	3.00	—	—	—
96 hours	4.56	2.94	4.57	3.10	—	—	—
1 week	4.50	2.46	4.31	2.86	4.24	4.30	4.19
4 weeks	3.95	—	4.22	—	4.20	4.19	4.20
5 weeks	4.28	—	4.30	—	—	—	—

[1] Since KOH serves to bind bromine in inorganic form, values obtained without addition of KOH to samples before ashing give an estimate of quantity of bromine combined with inorganic cations of samples.
[2] In this test five cartons were not opened for sampling until 24 hours after fumigation.

Table 6.—**Bromine residue in walnut meats ("pills," "pieces," and "halves") fumigated with 2.86 pounds methyl bromide per 1000 cubic feet at 28-inch vacuum; 90-minute exposure.**[1]

Days After Fumigation	Bromine Residue (Mg./100 Gm. Fresh Weight)			
	Pills	Pieces	Halves	Mean
11	3.49	3.51	3.32	3.44
18	2.94	3.37	3.30	3.20
25	3.02	3.32	3.32	3.22
32	3.14	3.28	2.94	3.12
39	3.00	3.31	3.05	3.12
46	2.92	2.94	3.22	3.03
53	3.34	3.34	3.18	3.29
Average	3.12	3.29	3.19	3.20

[1] Fumigated by the California Walnut Growers Association at their Vernon, California, plant.

of bromine combined with the inorganic cations of the samples. The same trend is shown in the cartons of nut meats held for 24 hours before opening and sampling. These cartons were not tightly sealed, and there were plenty of openings for the exchange of air. Bromine residues found in "pieces" and "halves" (Table 5) follow closely the amounts found in the "pills," with only insignificant variations.

In table 6 are presented the results of analyses for bromine residues in walnut meats fumigated with methyl bromide by the California Walnut Growers Association at their Vernon plant. These samples of standard packaged nut meats were subjected to 28-inch vacuum fumigation with 2 pounds of methyl bromide per 700 cubic feet (2.86 pounds/1000 cubic feet) for 90 minutes. Three different sizes of walnut meats, "pills," "pieces," and "halves," were analyzed over a period of 53 days for bromine residues. Results show that the bromine residues remained at about the same level, with some fluctuations, throughout the 53-day period. This holds true for the three different sizes of walnut meats. According to the data presented in table 6 the walnut meats absorbed an average of 3.20 mg. of bromine per 100 grams fresh weight, when fumigated according to the procedure described above.

SUMMARY AND CONCLUSIONS.—Results obtained in the fumigation chambers of the Division of Entomology of the University of California Citrus Experiment Station, indicate that satisfactory control of larvae of the navel orangeworm, *Myelois venipars* Dyar, in whole walnuts can be obtained by fumigating at atmospheric pressure with methyl bromide at dosages of 2 pounds per 1000 cubic feet for 2 hours when the nuts are in loosely woven cloth sacks. When the nuts are in sealed, double-walled cellophane bags, satisfactory control cannot be obtained at atmospheric pressure, with dosages of 2 to 4 pounds of methyl bromide, except probably at an exposure of more than 8 hours.

Results of the fumigation of larvae of the Mediterranean flour moth, *Ephestia kühniella* Zeller, in sealed, double-walled cellophane bags show that satisfactory control cannot be obtained at atmospheric pressure with dosages of methyl bromide at 2 to 12 pounds per 1000 cubic feet and exposures of 1 to 3 hours. Satisfactory control of the Mediterranean flour moth larvae was obtained at a dosage of 2 pounds methyl bromide per 1000 cubic feet, and an exposure of 1 hour, when either sustained or released vacuum was employed.

When whole walnuts in sealed double-walled cellophane bags were vacuum-fumigated with 2 pounds methyl bromide per 1000 cubic feet, the methyl bromide persisted over a period of 1 hour to 21 days within the bag, and the nuts absorbed 0.41 to 4.84 mg. bromine per 100 grams fresh weight during this time.

The bromine residue of shelled walnuts of the three different sizes fumigated under vacuum with 2.86 pounds methyl bromide per 1000 cubic feet, although very high at first, became almost constant after the first 24 hours of fumigation. Analysis carried out as much as 9 weeks after fumigation found the bromine residue at about the same level. Whole or shelled walnuts which have been subjected to vacuum fumigation with methyl bromide may be expected to show high bromine residues.

LITERATURE CITED

Dudley, H. C. 1939. Bromide content of fruits and vegetables following fumigation with methyl bromide. Ind. Eng. Chem., Anal. Ed. **11**: 259–61.

Studies with Aldrin and Dieldrin Against Melon Insects[1]

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Under certain conditions the agromyzid leafminer *Liriomyza subpusilla* Frost has proved to be highly destructive to the foliage of several varieties of melons. Where infestations are severe, a large proportion of the leaves may be more or less completely destroyed and the yield and quality of the melons greatly reduced. Serious injury due to sunburning of the fruit is a frequent and obvious restult. The nature of the injury to leaves of honeydew melons is shown in figure 1.

Normally the leafminer is not a serious pest early in the season. It becomes more abundant as the season advances and economic damage seldom occurs before mid-season in the Patterson area where most of the melon investigation work has been conducted.

Fig. 1.—Leaf of honeydew melon showing injury due to the larvae of the leafminer, *Liriomyza subpusilla* Frost.

The bionomics of the leafminer are poorly understood and are in need of thorough investigation. At the present time there is no way of predicting whether or not a serious infestation will develop. There are many factors which influence the population of leafminers and from observations to date it appears that insect parasites are quite important in this respect. During the past season several fields were observed where hymenopterous parasites successfully checked the miners after it appeared that they would increase to destructive levels. The most abundant parasite was a very small Eulophidae, *Solenotus intermedius* Gir. In addition the following parasites were reared in small numbers from larvae and pupae of the leafminer: *Chrysocharis ainsliei* Cwfd.; three undetermined males belonging to the family Pteromalidae and one Braconid in the genus *Opius*.[5]

Prior to the 1950 investigations, attempts to control this leafminer on melons with insecticides showed little promise. Chlordane and toxaphene have been reported in the literature as successful against other species of leafminers, but in our tests chlordane was ineffectual and toxaphene proved to be phytotoxic to all melon varieties on which it was applied.

During the 1950 season the new materials aldrin and dieldrin were tested in varying formulations, concentrations and number of applications. In order to compare results, weekly surveys were made at which time 100 leaves were picked at random from each plot and the number of mines in each leaf counted. Each leaf was then recorded in one of the following class intervals or categories:

0 mines per leaf
1–5 mines per leaf
6–10 mines per leaf
11–20 mines per leaf
more than 20 mines per leaf

Counts were made prior to the first application on August 8 and repeated at weekly intervals for seven weeks until harvest was completed.

Aldrin and dieldrin were used as emulsions in concentrated sprays and as dusts and were applied two or three times at two week intervals. The aldrin stock

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[5] Determined by Dr. C. F. W. Muesebeck and Dr. A. B. Gahan, U. S. National Museum.

Table 1.—Percentage of melon leaves having over 10 mines per leaf on survey dates given prior to and following applications of varying concentrations of aldrin and dieldrin sprays and dusts.

Survey Date	Check	Concentrated Sprays: Aldrin Pounds per Acre		Concentrated Sprays: Dieldrin Pounds per Acre		Dusts: Aldrin 2.5%	Dusts: Dieldrin 2.5%
		1	1.5	0.5	1		
		Two Applications: Aug. 8 and 22				Three Applications Aug. 8, 22 and Sept. 7	
Aug. 8	72	76	76	66	72	72	72
15	51	33	46	47	47	37	38
22	69	18	12	20	24	38	27
29	64	11	10	13	8	22	12
Sept. 5	65	3	7	3	1	33	1
12	84	20	22	6	2	54	17
19	77	14	9	2	4	28	8
		Three Applications: Aug. 8, 22 and Sept. 5[1]					
Sept. 12	84	5	9	7	5		
19	77	9	10	0	0		

[1] Survey data prior to Sept. 12, same as given above for two treatments.

emulsion contained 2 pounds of active material per gallon and the dieldrin contained 1 pound per gallon. The sprays were applied with either a ground rig or by a boom equipped airplane, and the dusts with a ground duster having three nozzles to the row. The plots varied in size from approximately one to ten acres. Where applications were made by air, 10 acre plots were used.

The ground spray applications were applied at approximately 20 gallons per acre and the dusts at 25 pounds per acre.

The materials used, amount of active insecticide per acre per treatment, number of applications and a summary of results are given in tables 1 and 2. The

Table 2.—Summary of percentages of infested melon leaves having over 10 mines per leaf between August 8 and September 19, 1950, following treatments with aldrin and dieldrin sprays and dusts.

	Spray	Dust	Total Effect as Spray and Dust
Aldrin	17	35	23
Dieldrin	15	17	16
Total effect of both materials as a spray or dust	16	26	

Pretreatment average for check: 72.3 ± 3.9.
Seasonal average for check: 68.8 per cent.

Table 3.—Comparative effectiveness of aldrin and dieldrin concentrated sprays applied by plane. Basis of comparison is the percentage of leaves having over 10 miners per leaf.

Survey Date	DDT Treated Check	Aldrin 1 Pound per Acre	Dieldrin 0.5 Pound per Acre
Aug. 22	79	—	—
29	37	12	24
Sept. 5	12	1	1
12	40	11	5
14	43	13	1

Treatments applied August 24 and Sept. 6.

seasonal trend of infestation for the different concentrations of aldrin and dieldrin sprays is shown in graph form in figure 2.

It is felt that the efficiency of a melon leaf is considerably reduced if it contains 20 or more miners and a leaf containing over 10 miners is approaching the point where some control methods should be employed. In the following tables and graphs, therefore, the treatments are compared on the basis of the number of leaves per plot with more or less than 10 miners per leaf. Since 100 leaves were examined per plot, these counts can be converted directly to percentages.

The pretreatment survey indicated

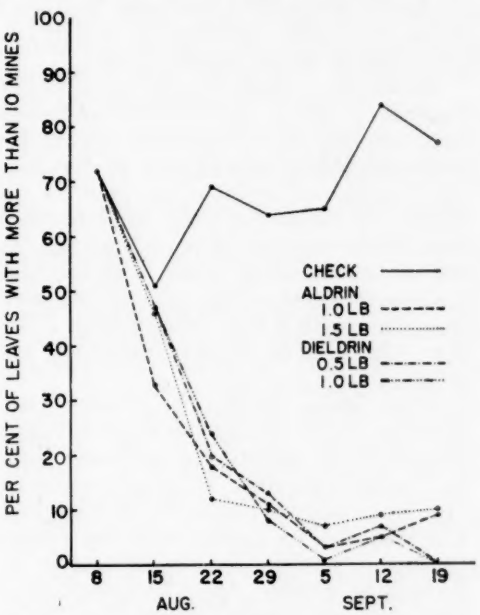

FIG. 2.—Trends of leafminer damage in treated and untreated plots. Insecticides applied Aug. 8, 22 and Sept. 5, 1950.

that the distribution of miners throughout all the plots was remarkably uniform. The average per plot was 72.3 ± 3.9 mines per leaf.

In table 2 where the results are further condensed, it is shown that sprays were more effective than dusts with a seasonal average of 16 per cent of the leaves with over 10 mines per leaf as compared to 26 per cent where dusts were used. Further, the data show that dieldrin is more effective than aldrin as a spray and as a dust. It can be noted that dieldrin as a dust is as effective as aldrin as a spray.

The higher concentrations of both aldrin and dieldrin do not seem to be warranted since the lower dosages appear to be nearly as effective as the higher ones. The effect on the miners is more a function of material rather than concentration of active ingredients in the range of our experiments.

It is furthermore doubtful if a third application is necessary since there was so little difference between the two and three spray treatments.

Figure 2 has been prepared to graphically illustrate the effectiveness of aldrin and dieldrin at different concentrations in reducing the number of leafminers in the leaves of honeydew melons. Here it is clearly shown that the lower dosage of each insecticide resulted in nearly as good control as the higher dosage.

AIRPLANE APPLICATIONS.—In another experiment aldrin and dieldrin emulsions were applied as concentrated sprays by airplane. Aldrin was applied at the rate of 1 pound of active ingredient in 10 gallons of water per acre. Dieldrin was used at the rate of 0.5 pound per acre in the same amount of water. Two applications were made and the treatments were compared with a plot treated with 3 per cent DDT. The results obtained are given in table 3.

From these results it is seen that dieldrin at 0.5 pound per acre is again more effective against the leafminer than is 1 pound of aldrin. It is interesting to note that injury in this field never reached a serious level for shortly after the second treatment was applied on September 6, it became evident that hymenopterous parasites, previously referred to, were going to check the leafminer population.

Aldrin and dieldrin were used in other fields and on other varieties of melons. In all cases they showed much promise in reducing the leafminer population and substantiated the data given in the above experiments.

In conducting the investigations with these materials every opportunity was taken to observe their action upon the melon plants as well as upon other insects and related pests. No phytotoxic effects were noted although it is possible that the 1.5 pound dosage of aldrin may have caused a slight bronzing of the foliage.

Both of these materials were highly toxic to honeybees. They also appeared to be very effective in killing such economic pests as darkling ground beetles, grasshoppers, and *Diabrotica* beetles. The melon aphid was not present in sufficient abundance to obtain an accurate measure of the effectiveness of these materials against this pest, but the few observations which were made indicated that both are somewhat effective. In one experiment where untreated checks were left, the aphid population was slightly greater than in the treated plots.

Observations were made which showed that both aldrin and dieldrin are effective against the melon leafhopper *Empoasca abrupta* DeLong. The trend of the leaf-

Table 4.—Comparative effectiveness of aldrin and dieldrin in controlling the melon leafhopper on honeydew melons, Patterson 1950. Comparisons based upon the number of leafhoppers per leaf.

Survey Date	Check	Concentrated Sprays[1]				Dusts		
		Aldrin Pounds per Acre		Dieldrin Pounds per Acre		Aldrin 2.5%	Dieldrin 2.5%	DDT 3%
		1	1.5	0.5	1			
		Two Applications: Aug. 8 and 22				Three Applications Aug. 8, 22 and Sept. 7		
Aug. 10	0.8	0.6	0.2	0.1	0.2	0.8	0.8	—
17	0.4	0.2	0.7	0.1	0.1	0.0	0.0	—
24	0.6	0.3	0.3	0.1	0.0	0.2	0.0	0.0
31	0.9	0.9	1.6	0.1	0.1	0.0	0.0	0.0
Sept. 8	4.8	0.8	1.3	0.3	0.1	0.0	0.0	0.0
14	6.3	0.0	1.9	0.3	0.0	0.0	0.0	0.0
19	3.4	1.4	1.5	0.1	0.0	0.0	0.0	—
Oct. 2	3.9	0.4	5.1	0.3	0.4	0.0	0.0	0.0
		Three Applications: Aug. 8, 22 and Sept. 5[2]						
Sept. 14	6.3	0.1	0.9	0.0	0.0			
19	3.4	1.2	0.1	0.0	0.0			
Oct. 2	3.9	0.4	0.3	0.0	0.0			

[1] Sprays applied in 20 gallons of water per acre. Dust applied at 25 pounds per acre.

[2] Survey data prior to Sept. 14, same as given above for two applications.

hopper population was followed wherever these insecticides were used. The results obtained in one of the more extensive series of tests are given in table 4.

Dieldrin in both concentrations as a spray proved to be superior to aldrin and the 8 ounce concentration per acre appeared to be as satisfactory as the 1 pound. These experiments were set up for leafminer control and as a result the spacing and number of applications is not that which woulld be most suitable for leafhopper control. Both aldrin and dieldrin dusts were remarkably effective and appeared as good as 3 per cent DDT.

The Pacific mite was present in all the plots but in no case did destructive populations arise which could be associated with treatments.

SUMMARY.—The dipterous leafminer *Liriomyza subpusilla* Frost is a serious pest of melons in California with destructive populations usually resulting late in the season. Under favorable conditions for the miners, melon plants may lose a large portion of their foliage, resulting in reduced yields and quality. The ecology of the miner is not well known, but it is apparent that natural enemies are important in regulating the population. In several fields where serious injury threatened, parasitism by several species of Hymenoptera reduced the miner population to a non-destructive level.

Aldrin and dieldrin used as sprays and dusts by ground and air showed much promise in controlling the leafminer. Dieldrin proved to be more effective than aldrin irrespective of formulation, and sprays were better than dusts. Dieldrin was applied at the rate of 0.5 and 1.0 pound per acre as sprays and as a 2.5 per cent dust. Aldrin was applied at the rate of 1 and 1.5 pounds per acre as sprays and likewise as a 2.5 per cent dust. There appeared to be more differences between materials than between concentrations of the same spray material. Two and three applications were made.

It was noted that both of these materials were quite toxic to honeybees, a condition which should be taken into consideration when applying. These insecticides are also effective against other important pests of melons such as *Diabrotica* beetles, darkling ground beetles and the melon leafhopper, *Empoasca abrupta* DeLong. Against the leafhopper, dieldrin has a longer residual action and is more effective than is aldrin. Dusts appear to be quite good.

These materials have not as yet been licensed for use in California, except for aldrin upon cotton and for grasshoppers on forage crops.

Although the results with aldrin and dieldrin look very promising, further studies are highly desirable before these materials can be safely recommended for general use.

Toxicity of Organic Insecticides to Honey Bees: Contact Spray and Field Tests[1]

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Organic insecticides have proven far less harmful to honeybees than are the arsenicals. When DDT and the other chlorinated hydrocarbons were receiving popular publicity as universal insect killers there was a widespread fear among the beekeepers that they would have to vacate intensively cultivated areas. These fears have proven baseless and commercial beekeepers have obtained surplus honey in areas which were uninhabitable by bees when arsenical poisons were used almost exclusively on field crops. Farmers can carry out their insect control programs without serious loss of pollinators. Unfortunately, losses of honeybees due to insecticides still occur. Entire colonies are seldom killed by the chlorinated hydrocarbons, but almost all of the field bees may at times be killed, which results in decreased honey production for the beekeeper and fewer pollinators for the farmer. In addition to this some of the organic insecticides repel bees to varying extents, and a loss of pollination and honey storage may result.

Both the toxicity and the repellency of organic insecticides to honeybees seem to vary considerably, and the reason for the variation is not understood. In order to

[1] Technical Contribution No. 1455, Texas Agricultural Experiment Station.

gain information on the effects of chlorinated hydrocarbons on bees a series of tests was begun in 1948. The toxicity to honeybees of several organic insecticides when used as contact dusts, as stomach poisons and when applied to field crops visited by bees, has been reported (Weaver 1949, 1950). The work herein reported was conducted at College Station, Texas during 1949 and 1950 to determine the toxicity of benzene hexachloride, DDT, chlordane and toxaphene when sprayed directly on bees and when applied to cotton in the field for the control of injurious insects.

LABORATORY TESTS.—The following commercial emulsible insecticides: (1) gamma benzene hexachloride, (2) gamma benzene hexachloride-DDT (3-5), (3) DDT, (4) chlordane, and (5) toxaphene were diluted with water for the contact spray tests. The spray equipment was similar to that described by Gaines & Dean (1949). A solid cone type nozzle delivered the equivalent of 8 gallons of spray per acre at 40 pounds pressure. To avoid any fumigation effect the sprays might have, bees were left in the cylinder only 30 seconds after the spray was released. The methods of handling the bees and the cages were the same as those used in the contact dust experiments (Weaver 1949).

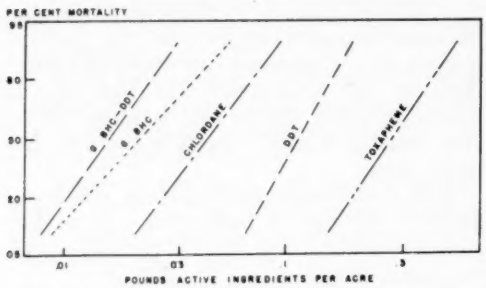

FIG. 1.—Dosage-mortality curves for the toxicity to the honeybee of insecticides as indicated when sprayed directly on bees.

The dead were removed from the cages daily for three days. In each series four replicate cages of 50 bees were treated with a predetermined dose of insecticide, and four additional cages of bees were left untreated to serve as checks. A minimum of five dosage levels which included 20 cages, or 1000 individuals, were used to calculate each dosage-mortality curve. Abbott's formula was used to calculate the percentage mortalities. Dosages, calculated as pounds of technical insecticide per acre, were converted to logarithms, the per cent mortalities to probits, and the dosage-mortality curves were calculated by the method of Bliss (1938).

RESULTS.—Dosage-mortality curves for gamma benzene hexachloride, 3 parts gamma benzene hexachloride-5 parts DDT, DDT, chlordane, and toxaphene when used as contact sprays on honeybees are shown in figure 1. The average temperature range during the tests was from 73° to 75° F., and the average range of relative humidity was from 57 to 65 per cent. Insecticides containing benzene hexachloride were, as in the contact dust tests, the most toxic materials tested. The median lethal dosage of gamma benzene hexachloride was 0.020 pound per acre, of the benzene hexachloride-DDT mixture at 0.015 pound per acre. It will be seen from figure 1 that chlordane was more toxic than DDT in these tests, whereas it was less toxic than DDT as a dust. In view of the variation in toxicity exhibited by chlordane as a dust, the increased toxicity over DDT as a spray is not especially surprising. The median lethal dose (MLD) of chlordane as a spray was 0.038 pound per acre. As a spray, in contrast to the contact dust and stomach poison action, there was no more striking variation in the toxicity of chlordane than of any of the other insecticides. The MLD of DDT as a spray was 0.089 pound per acre. Twenty per cent toxaphene dust applied at 36 pounds per acre (7.2 pounds technical toxaphene) killed only 5 per cent of the bees. The MLD of toxaphene spray was 0.224 pound of toxaphene per acre.

The dust and spray tests were not conducted simultaneously, so no exact comparisons can be made between the two types of treatment. The results, however, indicate that sprays are more toxic to bees than dusts under the conditions of these tests. After being dusted the bees performed cleansing operations and particles of dust could be found on the bottom of the cages to which the bees were transferred after dusting. It is doubtful that they were able to remove appreciable quantities of toxicant from their bodies after being sprayed with the insecticide. This may account, in part at least, for the

differences in toxicities of dusts and sprays. It is quite possible, however, that sprays on plants will be less toxic to visiting bees than dusts, since they may adhere to the plants more firmly than dusts.

FIELD TESTS.—Cages 6 by 6 by 36 feet were set up over cotton in the Brazos Valley as described in papers referred to above. Each contained a two-frame nucleus with a pound of bees. The bees that went into the cages were shaken from several colonies into a common container, mixed well, and weighed into the nuclei hives. The initial strengths of the nuclei were estimated by weighing samples of about 500 bees. Except for the aphicide treatment noted below, a check cage received no insecticidal treatment, and only one insecticide was applied to the cotton inside the other cages.

After a month there was increasing mortality in the check cage and the bees in the nuclei were replaced. At that time a heavy aphid infestation was damaging the cotton in some of the cages. Two days before new bees were introduced into the nuclei, all cotton was sprayed with 1 pound per acre of the systemic insecticide, octamethyl pyrophosphoramide, which Metcalf & March (1949) found to be virtually harmless to bees. There was some loss of bees in the nuclei that were left in the cages during the treatment, but little or no mortality occurred in the nuclei which were removed from the cages during spraying and returned as soon as the application was completed. When the tests were discontinued a month later the cotton was still almost entirely free of aphids, but there was no indication at any time that the nectar of the cotton was toxic to bees.

The following dusts: (1) 3 per cent gamma benzene hexachloride (2) 3 per cent gamma benzene hexachloride-5 per cent DDT-40 per cent sulfur (3) 10 per cent DDT-40 per cent sulfur (4) 10 per cent chlordane-40 per cent sulfur and (5) 20 per cent toxaphene-40 per cent sulfur, were applied in eight weekly treatments in dosages ranging from 10 to 40 pounds per acre. The same number of applications of toxaphene and toxaphene-DDT (2-1) sprays were applied in dosages ranging from 2 to 5 pounds of technical insecticide per acre. The average percentages mortality for the first three days following applications of an average of 18 pounds per acre of the dusts and 3.5 pounds per acre of the sprays are shown in figure 2. After the third day there was little death due to insecticides.

Nectar secretion during most of these tests was not nearly so profuse as in 1949. There was usually some secretion from the nectaries of open blossoms, but seldom was there any nectar on the nectaries of squares or small bolls. Commercial apiaries in the area produced less than half as much cotton honey as in 1949. In the

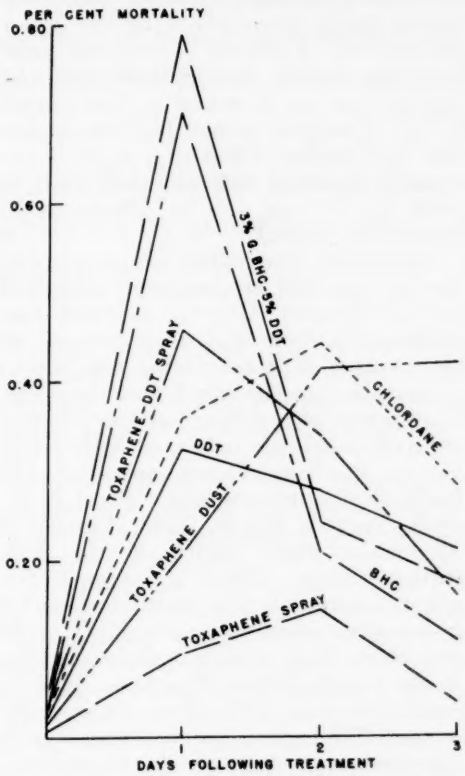

FIG. 2.—Average percentages mortality of honeybees for the first three days following applications to cotton of insecticides as indicated.

cages there was undoubtedly less cotton per bee than was available to bees in open fields. This over-crowding may have decreased the percentage of nectar-gathering bees and thus decreased the percentages mortality in the cages below the level that would have occurred if there had been more nectar available.

Eight applications of toxaphene spray killed only 0.7 per cent of the bees. Severe burning of the cotton plants, which resulted from the application of

5 pounds per acre, could have been, in part, responsible for the low mortality. Though fruiting continued, there was seldom any nectar secreted and consequently the bees seldom worked the cotton except during the first four tests. The mortality up to that time had been extremely low, so the burning may not have effected the results greatly.

The toxaphene-DDT spray killed a total of 9.1 per cent of the bees during the season. When nectar was abundant the bees continued to work while the cotton plants were wet with the spray and smelled of solvent. There was some leaf burn due to this material, but the damage was not as heavy as that caused by the toxaphene spray. The two sprays were formulated differently, so it is extremely doubtful that the difference in plant injury was due to differences in insecticide content.

Toxaphene dust killed 8.3 per cent of the bees in 1950, as compared to only 3 per cent in 1949. After the heaviest dust applications there was some decrease in the number of bees visiting the cotton as compared to the check, but there was no evidence of repellency at low dosages.

DDT dust again exhibited little repellency in our tests. This is contrary to the findings of other workers: (Todd *et al.*, 1949, Way & Synge, 1948, Linsley & MacSwain, 1947, Smith *et al.*, 1948, Butler & Shaw, 1949). According to frequent counts of bees gathering nectar from cotton inside the cages, DDT applications resulted in only a slight decrease in the number of working bees, however exact data were difficult to obtain since, in the DDT cage, a bee was often seen to approach a nectary with her proboscis extended, hover an instant, and then fly to another blossom. In the other cages bees either remained inside the nuclei, flew high over the cotton without approaching blossoms, or gathered nectar readily. The total mortality due to 8 applications of DDT was 9.9 per cent.

In contrast to its action in 1949, chlordane exhibited a marked repellent effect on the bees. The total mortality due to chlordane in 1949 was 25 per cent. In 1950 only a few bees were observed visiting cotton, and the mortality was 9.1 per cent.

Cotton was dusted with 3 per cent gamma benzene hexachloride in one cage in order to obtain a comparison between DDT alone, benzene hexachloride alone, and a mixture containing 3 per cent gamma benzene hexachloride and 5 per cent DDT-40 per cent sulfur (3-5-40). One test in 1949 indicated that neither benzene hexachloride nor DDT was repellent to bees but that 3-5-40 was somewhat repellent. These results were not borne out during 1950. Benzene hexachloride used alone was considerably less repellent than 3-5-40, but it was more repellent than any of the other insecticides except chlordane. The 3-5-40 was somewhat repellent to bees during the entire week following a dust application. This was in contrast to the results in 1950, when it appeared to be repellent only during the morning of the first day following applications. There were, however, more bees killed by 3-5-40 in 1950 than in 1949. The total mortality due to eight applications of 3-5-40 and BHC were 10.4 and 8.3 per cent respectively.

Toxaphene dust was used more than any other insecticide near the commercial apiaries under observation during 1950, however other chlorinated hydrocarbons were applied to cotton within the flight range of the bees. No noticeable reduction in hive populations occurred.

SUMMARY AND CONCLUSIONS.—A study was made of the toxicity of five organic insecticides when sprayed directly on honeybees. The decreasing order of toxicity was, 3 parts gamma benzene hexachloride-5 parts DDT, gamma benzene hexachloride, chlordane, DDT and toxaphene. Comparison with previous tests indicate that sprays are more toxic than dusts when applied directly to bees.

Bees inside large cages were allowed to work cotton which had been treated with insecticides. Toxaphene spray exhibited little toxicity to bees, but 2 parts toxaphene-1 part DDT spray, and dusts of 20 per cent toxaphene, 10 per cent DDT, 3 per cent gamma benzene hexachloride, 3 per cent gamma benzene hexachloride-5 per cent DDT, and 10 per cent chlordane killed from 8.2 to 10.4 per cent of the bees in eight applications. Applications of chlordane, benzene hexachloride, and benzene hexachloride-DDT dusts resulted in a marked decrease in the number of bees gathering nectar from the cotton. Little repellency due to DDT or toxaphene was noted.

LITERATURE CITED

Bliss, C. I. 1938. The determination of the dosage-mortality curve from small numbers. Quart. Jour. Pharmacy and Pharmacology. **11**: 192–216.

Gaines, J. C. and H. A. Dean. 1949. Effect of temperature and humidity upon the toxicity of certain insecticides. JOUR. ECON. ENT. **42**: 429–33.

Linsley, E. G. and J. W. MacSwain. 1947. Factors influencing the effectiveness of insect pollinators of alfalfa in California. JOUR. ECON. ENT. **40**: 349–57.

Metcalf, Robert L. and Ralph B. March. 1949. Studies on the mode of action of parathion and its derivatives and their toxicity to insects. JOUR. ECON. ENT. **42**: 721–8.

Shaw, F. R. and G. D. Butler. 1949. The effect of DDT, benzene hexachloride and parathion on the honeybee. JOUR. ECON. ENT. **42**: 855–6.

Smith, Roy F., J. W. MacSwain, E. G. Linsley and F. R. Platt. 1948. The effect of DDT dusting on honeybees. JOUR. ECON. ENT. **41**: 690–971.

Todd, Frank E., F. V. Lieberman, W. P. Nye and G. F. Knowlton. 1949. The effect of field applications of insecticides on honeybees. Agr. Chem. **4**: 27–29, 77.

Way, M. J. and A. D. Synge. 1948. The effects of DDT and of benzene hexachloride on bees. Ann. Appl. Biol. **35**: 94–109.

Weaver, Nevin. 1949. The toxicity of certain organic insecticides to honeybees. JOUR. ECON. ENT. **42**: 973–5.

Weaver, Nevin. 1950. Toxicity of organic insecticides to honeybees: Stomach poison and field tests. JOUR. ECON. ENT. **43**: 333–7.

Studies of the Flight Habits of Three Species of Flies Tagged with Radioactive Phosphorus[1]

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Knowledge concerning the natural dispersion of insects by flight is of considerable importance in control efforts. The development of local strains of DDT-resistant flies has increased interest in the distance flies will disperse from a given location. In studies conducted in Montana, Parker (1916) found that house flies dispersed nearly 2 miles. Bishopp & Laake (1921), in experiments at Dallas, Texas, determined that house flies, *Musca domestica* (L.), dispersed 13 miles, *Phormia regina* (Meig.) 10.9 miles, *Lucilia sericata* (Meig.) 1.2 miles, and *L. caesar* (L.) 3.5 miles.

In order to obtain more information on the dispersion of flies, a preliminary experiment with new method of tagging involving the use of radioactive phosphoric acid, was conducted near Corvallis, Oreg., in September 1950.

DESCRIPTION OF AREA.—The study was conducted in the Willamette Valley south of Corvallis. The area is flat except for low hills in the western part, beginning approximately 3 miles from the release point. Vegetation in the hilly area is second-growth fir and vine maple. Dense growths of large oak trees flourish along Muddy Creek, a meandering stream flowing through the center of the area, and smaller growths of trees are scattered throughout the valley. The greater part of the land, especially north and south for a distance of 20 miles from the release point, is utilized in the production of small grains and grass seed. At the time of the experiment the fields either were in stubble or were plowed. Farmsteads are located from one-half mile to a mile apart over most of the area.

REARING AND TAGGING OF FLIES.—The house flies used in this test were obtained from a laboratory colony that had been reared in confinement since 1941. The blowflies *Phaenicia sericata* and *Phormia regina* were obtained from eggs collected in the field and reared on horse meat in the laboratory. When the larvae had pupated, the pupae were removed from the rearing medium and placed in lots of 1,000 to 3,000 in screen-wire cages. The flies emerged over a period of 7 days, during which time they were provided with food and water.

The day before release food and water were withheld, and an aqueous solution of radioactive phosphoric acid containing P^{32} was provided so that the flies could become radioactive by feeding. Each

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group of 1,000 flies was provided with 12 ml. of tap water containing 20 μc (microcuries) of P^{32} and a small amount of sugar in a beaker or petri dish. Crumpled paper toweling in each vessel prevented drowning. The amounts of P^{32} and water were adjusted so that all the flies would have ample opportunity to drink and become radioactive. It was desired to have each fly show radioactivity of approximately 2,000 cpm (counts per minute). They were tested on a standard laboratory monitor equipped with a Geiger-Müller tube having a window thickness of 2.0 mg./cm.^{2}. Radioactivity tests on the flies before release showed that approximately 90 per cent gave readings from 200 to 5,000 cpm.

To provide a further check on the tagging, approximately 7,500 of the radioactive house flies were colored by shaking them in a sack containing red paint pigment.

METHOD OF CAPTURING FLIES.—Screen wire cone-type fly traps were constructed similar to those described by Bishopp (1930) but smaller (22 by 12 inches). The 24 traps were set concentrically around the release point at distances of 0.5, 1, 2, 3, and 4 miles, 6 traps on each of the 0.5 and 1-mile circles and 4 on each of the others, in the four cardinal directions. One-half pound of liver that had been allowed to decompose in a closed container was placed in the bait pan of each trap early in the morning of the day of release, and 2 quarts of a fermented mixture of brown sugar and water was added as a lure. The traps were rebaited after 8 days.

Since radioactive flies were caught in all traps within 1 day after release, the traps in the inner circle were moved out to 8 and 12 miles from the point of release. Seven days after the beginning of the experiment two traps were set at each of two locations 15 and 20 miles to the south.

Flies were removed from the traps 1, 2, 4, 8, 12, and 20 days after the release, after they had been killed with a pyrethrum-carbon tetrachloride mixture. A total of 141 trap catches were made. The catch from each trap was weighed, and the flies in a 5-gm. sample were identified as to species or genus. Each catch was examined with the laboratory monitor to determine the number of radioactive, or tagged, flies.

NUMBER OF FLIES RECAPTURED AND DISTANCE OF DISPERSION.—Approximately 36,000 *Musca domestica*, 15,000 *Phaenicia, sericata* and 1,200 *Phormia regina* flies, about equally divided as to sex, were released at 10 a.m. on September 6. An 8-m.p.h. wind was blowing from the Northwest, and the weather was clear. The average mean daily temperature for the 21-day period of test was 64.2° F. (mean maximum 79°, mean minimum 49.4°), and the prevailing winds were from the Northwest. The percentages of radioactive flies recaptured at various distances from the center are shown in table 1. Of the recaptured flies 68 per cent of *M. domestica*, 48 per cent of *P. sericata*, and 64 per cent of *P. regina* were females. All three species were recovered in greatest numbers in the traps 0.5 mile from the release point, and as the distance increased the numbers caught decreased.

Table 1.—Per cent recovery of radioactive flies at different distances from the release point.

DISTANCE OF TRAP FROM CENTER MILES	*Musca domestica*	*Phaenicia sericata*	*Phormia regina*
0.5	3.8[1]	1.81	9.08
1	.58	1.33	3.75
2	.14	.27	.75
3	.038	.067	.25
4	.07	.14	.083
6	.008	—	0
7	.0027	—	0
8	0	—	.083
12	.011	—	—
Total	4.6	3.6	14.0

[1] Some flies lost because one trap was disturbed.

Musca domestica was recovered 12 miles, *Phaenicia sericata* 4 miles, and *Phormia regina* 8 miles from the center. No tagged flies were caught in the traps placed at the 15- and 20-mile locations, probably because they were placed there several days after the initial release of flies. Of the colored house flies released, 4.1 per cent were recovered, as compared with 4.6 per cent of the radioactive flies. Most of the colored flies were caught during the first day, at traps located on the 0.5 mile circle.

Most of the tagged flies caught 0.5 mile from the center were in a trap on a farmstead east of the center. Another trap,

Table 2.—Total numbers of tagged and untagged flies caught on different days after their release.

DAYS	TAGGED FLIES			UNTAGGED FLIES		
	Musca domestica	*Phaenicia sericata*	*Phormia regina*	*Musca domestica*	*Phaenicia* spp.	*Phormia regina*
1	1529	358	138	5848	12,005	44,050
2	81	119	18	2361	8,124	22,573
4	53	41	8	4145	5,881	25,058
8	10	15	2	3900	7,216	19,302
12	0	10	2	2205	4,690	16,350
20	2	0	0	—	—	—
Total	1675	543	168	18,456	37,916	127,333

located near farm buildings west of the center, was observed to contain numerous colored flies at 4 P.M. on the day of release, but because children had removed the lid most of the flies had escaped when the trap was examined the next morning.

The fact that several of the tagged flies passed over many farmsteads and other places harboring oviposition sites and food material, and house flies dispersed over Corvallis to the north and Monroe to the south, suggests, as Bishopp (1921) points out, that house flies have a strong migratory tendency and will pass by breeding grounds and food sources. There is every reason to expect that DDT-resistant flies will exhibit similar tendencies and resistant strains will gradually spread over an area.

COMPARATIVE NUMBERS OF TAGGED AND UNTAGGED FLIES CAUGHT.—Table 2 gives the total numbers of tagged and untagged flies caught on different days. It will be observed that most of the tagged flies were caught the first day, but it is believed that if the inner traps had not been moved the total number of flies caught would have been greater, since numerous tagged flies were probably present in the center. In support of this is the fact that the traps located 1 mile from the release point captured only 16 per cent fewer tagged flies on the second day than on the first day. Twelve days after release only 12 tagged flies of all species were recovered.

There was also a gradual decrease of untagged flies after the first day, but the percentage decrease was less than for the tagged flies. When the daily collections of all three species were averaged, about 90 per cent fewer flies were caught per day towards the last of the experiment. The traps themselves might have reduced the fly population. The weather did not appear to be a factor, although the bait gradually became less attractive in luring flies.

The ratio of total numbers of radioactive to nonradioactive flies was 1:11 for *Musca domestica*, 1:70 for *Phaenicia* spp., and 1:758 for *Phormia*. These ratios give some clue as to the normal population of flies in the area. *Phormia regina* was the most abundant species and comprised 50 per cent of all flies caught. *Phaenicia* spp. and *Musca domestica* comprised approximately 15 per cent and 7 per cent of the total flies captured. Approximately 90 per cent of the *Phaenicia* flies caught were *P. sericata*. Other genera of Muscidae represented in the catches were Calliphora, Sarcophago, Ophyra, and Muscinia. Considerable numbers of Lepidoptera and Vespidae were present, the latter feeding to some extent on the flies.

RELATION BETWEEN TRAP LOCATION AND CATCH OF FLIES.—The location of fly traps is of considerable importance in capturing flies. Of the 24 traps set out in a 4-mile radius, only 7 were considered to be set in a good environment, at least for house flies, and these were located in barnyards. The others were placed on fence posts in open stubble fields. Table 3, summarizing the numbers of flies taken in these two locations in the first three trap collections, shows that the barnyard location accounted for about two to six times as many flies per trap as the field location. However, a few more of the tagged *Phaenicia* flies were caught in the field. The barnyard settings were extremely attractive to house flies, since about 18 times as many tagged flies were captured there as in the field. The capture of a high percentage of tagged flies with a few favorably located traps suggests that

the use of traps in control projects would materially reduce fly populations.

DIRECTION OF FLIGHT.—The numbers of tagged flies caught in traps located in different directions from the point of release are given in table 4. The large number of tagged house flies caught in the east trap on the half-mile circle indicates that this direction was preferred. However, the data for traps on the 2-, 3-, and 4-mile circles show that fewer house flies were taken in the east traps. No *P. regina* flies were taken in the west traps. In general, house flies and *P. sericata* disseminated in every direction from the point of release, although the prevailing winds were from the north. The most distant records of recaptured house flies (12 miles) were obtained north and south, but no traps were located at this distance to east and west.

Table 3.—Average numbers of tagged and untagged flies captured per trap in two environments during the first three trap collections.

SPECIES	IN BARNYARD (17 COLLECTIONS)	IN FIELD (43 COLLECTIONS)
Untagged flies:		
Musca domestica	454	73
Phaenicia sericata	909	209
Phormia regina	2242	1152
Tagged flies:		
Musca domestica	84.0	4.6
Phaenicia sericata	6.0	8.6
Phormia regina	8.6	1.6

COLORING VERSUS P^{32} AS A MEANS OF TAGGING.—The writers consider that use of P^{32} is greatly superior to coloring as a means of tagging flies for flight studies. Although flies colored with paint pigment can be recovered later, much work is required in sorting large catches to find the specimens. Moreover, the color rubs off, and after 48 hours the pigment adheres mainly around the halteres and is difficult to see. P^{32}-tagged flies can be easily located with a Geiger counter, and large catches of flies that do not contain radioactive specimens can be examined in a few moments.

SUMMARY.—Three specimens of flies were tagged by feeding them solutions of radioactive phosphoric acid (containing P^{32}) and then released in an agricultural area south of Corvallis, Oreg. A total of approximately 36,000 *Musca domestica* (L.), 15,000 *Phaenicia sericata* (Meig.), and 1,200 *Phormia regina* (Meig.) flies were released, of which 4.6, 3.62, and 14 per cent of the respective species were recovered. A total of 24 fly traps encircled the release point at 0.5, 1, 2, 3, 4 miles the first day, after which the traps in the inner circle were moved farther out. *M. domestica* was recovered 12 miles, *P. sericata* 4 miles, and *P. regina* 8 miles from the center. Most of the tagged flies were caught the first day in the traps 0.5 mile from the release point. Tagged flies had moved outward 4 miles in each cardinal direction the first 24 hours after release.

The ratio of tagged to untagged flies caught in the traps was 1:11 for *Musca domestica*, 1:70 for *Phaenicia* spp., and 1:758 for *P. regina*. *P. regina* comprised approximately 50 per cent, *Phaenicia* spp. 15, and *M. domestica* 7 per cent of the total number of flies caught. Traps set in barnyards caught several times as many house flies and *Phaenicia* as those set in open fields.

The use of radioactive phosphorus as a means of tagging flies has proved satisfactory and reduces the amount of work in examining large catches of flies over that necessary when pigmented dusts are used to color the insects.

LITERATURE CITED

Bishopp, F. C., and E. W. Laake. 1921. Dispersion of flies by flight. Jour. Agr. Res. **21**(10): 729–66.
Bishopp, F. C. 1930. Fly traps and their operation. U. S. Dept. Agr. Farmers Bul. **734.**
Parker, R. R. 1916. Dispersion of *Musca domestica* (L.) under city conditions in Montana. JOUR. ECON. ENT. 9(3): 325–54.

FIRST MEETING OF AAEE

Mr. James Fletcher, president of the Entomological Club of the American Association for the Advancement of Science issued a call to those interested in the formation of an Association of Official Economic Entomologists, and as a result an organization meeting was held at Toronto, Canada, on August 29 and 30, 1889. A constitution was adopted at this meeting and C. V. Riley was elected president, S. A. Forbes, first vice-president, A. J. Cook, second vice-president, and John B. Smith, secretary. In all there were about 23 charter members.

Stable Fly Control on Dairy Animals with Piperonyl Butoxide-Pyrethrins[1]

EPHRIAM HIXSON AND MARTIN H. MUMA, *University of Nebraska, Lincoln*

Most of the known chlorinated organic insecticides are believed to be hazardous to human health. This is indicated in data published and summarized by Lehman (1948, 1950). At the present time only methoxychlor appears to be safe to use as a spray both on and around dairy animals. In 1948, when it became apparent that the use of chlorinated insecticides around dairies would have to be restricted, a piperonyl butoxide-pyrethrins formulation was included in stable fly, *Stomoxys calcitrans* (L.), control tests conducted in Nebraska by Muma & Hixson (1949). The same and similar formulations of this synergist and pyrethrins have now been tested for 3 years.[2]

Pyrethrum extracts and formulations have been used to control stable flies for at least a quarter of a century. Howard (1926) reported satisfactory control of stable flies by regular sprayings with pyrethrum extract in conjunction with fly traps. Pyrethrum control studies since 1926 have included treating larvae and larval developmental areas, Buchmann (1929a, 1929b), pyrethrum soaps, Cory & Eaton (1929), pyrethrins in refined kerosene, Eagleson (1938), pyrethrum thiocyanate oils, Howell & Fenton (1949) and systemic control in the laboratory by permitting stable flies to feed on rabbits previously fed pyrethrum, Lindquist *et al.* (1944). Since synthesis of the synergist piperonyl butoxide, (Wachs 1947), stable fly control with piperonyl butoxide-pyrethrins formulations has been reported by Dove (1947), and Donohoe & Cowling (1948).

Stable fly control tests reported in this paper were conducted to check the efficiency of piperonyl butoxide-pyrethrins as animal treatments and to determine the maximum spacing of such treatments for effective control under eastern Nebraska conditions.

PROCEDURE AND METHODS.—All tests were conducted under active dairying conditions. With the exception of animal treatments made with power equipment, sprays were applied to the animals by instructed milkers. Sprays were applied while animals were in the stanchions except for the 1950 semi-weekly treatments. These were applied in a holding pen. Animals were not confined to specific pasturage unless that had been the usual practice. All observations and fly counts were made under field conditions without restriction of the animals.

1949 TESTS.—In the summer of 1949 all experimental animals were located on one large dairy farm. Four separately pastured herds of cattle were utilized. Herd 1 consisted of 32 cows that were milked twice a day, herd number 2 of 18 cows milked three times a day, herd 3 of 18 heifers and herd 4 of five dry cows. With the exception of herd 3 all herds had access to comparable barnyards and sudan or brome grass pasture. The heifer herd was located in a pasture half of which was brome and half sudan. In addition they had access only to an isolated shed with no yard or silage feeding facilities. Herds 1 and 2 were milked in the same barn but at different times.

Sprays were applied in three different ways. From July 2 to July 24, treated herds received three treatments spaced at intervals of 6 to 8 days. These sprays were applied with a power spray machine operating at 200 pounds pressure. Two quarts of spray mixture were applied to each animal. A 2 quart hand mist sprayer was used to apply light daily sprayings from July 25 to August 3. From August 4 to September 9 daily sprays of 0.5 pint of spray per animal were applied with a 3 gallon compressed air sprayer. Two different piperonyl butoxide-pyrethrins formulations were used. One was an emulsion concentrate containing 10.0 grams technical piperonyl butoxide, 1 gram pyrethrins and 12.5 grams of emulsifier in 76.5 grams of deodorized base oil. The other was a wettable powder containing 10 per cent technical piperonyl butoxide and 0.75 per cent pyrethrins in inert carriers. Herd number 1 was treated with the emulsion concentrate diluted 1 to 15 with

[1] Published with the approval of the director as Paper No. 522, Journal Series, Nebraska Agricultural Experiment Station.

[2] All formulations supplied by U. S. Industrial Chemicals, Inc.

water throughout the test. Herd 2 was treated with a suspension of 1 pound of the wettable powder in 2.5 gallons of water for the power sprayings and with the emulsion for the remainder of the test. Herd 3 was treated with the same suspension as herd 2 for the power sprayings but was later dropped from the test because of the uncomparable pasture and yard conditions. Herd 4 was left untreated as a control.

Herd 1 received approximately 13.3 grams of piperonyl butoxide and 0.13 gram of pyrethrins per animal with the power sprayer but only 3.3 and 0.03 grams respectively with the compressed air sprayer. Herd 2 received 9.28 grams of piperonyl butoxide and 0.07 gram of pyrethrins with the power sprayer and the same as herd 1 with the compressed air sprayer. Herd 3 received the same amount as herd 2 with the power sprayer. Dosages for the hand mist sprayer were not computed.

Evaluation of treatments was based on daily counts of the number of stable flies per animal on a sample of 10 animals from each treated herd and on five animals in the control herd. Counts were made simultaneously on each side of an animal by two observers. All counts were made between 10:00 A.M. and 12:00 M. Location of the animals and weather, including light, wind, precipitation and temperature were recorded for the time of each count.

1950 TESTS.—Experimental herds were located on three separate dairy farms in 1950. At one dairy, the same as that used in 1949, herd number 1 consisted of 30 to

Table 1.—Mean number of stable flies per unsprayed dairy cow at computed and theoretical mean temperatures when fly counts were made on animals located in the barnyard or on brome or sudan grass pasturage under light or moderately windy conditions, Lincoln, Nebraska, Summer 1949.

MEAN TEMPERATURES	MEAN NUMBER OF FLIES PER ANIMAL					
	Light Wind			Moderate Wind		
	Yard	Brome	Sudan	Yard	Brome	Sudan
Computed						
73° F.			9.4			
75° F.				22.3		
77° F.	32.6					
80° F.					10.4	
82° F.						6.4
85° F.		10.9				
Theoretical						
85° F.	36.0	10.9	10.9	25.3	11.0	6.6

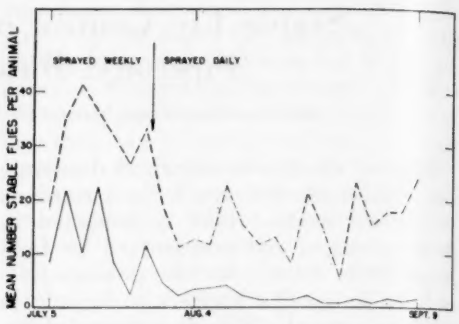

FIG. 1.—Mean number of stable flies per animal per three day period on sprayed (solid line) and unsprayed (dashes) dairy cows from July 2 to September 9, 1949 at Lincoln, Nebraska, All treatments were made with a piperonyl butoxide-pyrethrins emulsion or suspension.

32 cows milked twice a day, herd number 2 of 16 to 18 cows milked three times a day and the control herd of 4 to 16 dry cows and heifers. At the second dairy the treated herd consisted of 18 cows milked twice a day and the control herd of 10 to 12 heifers. At the third dairy the treated

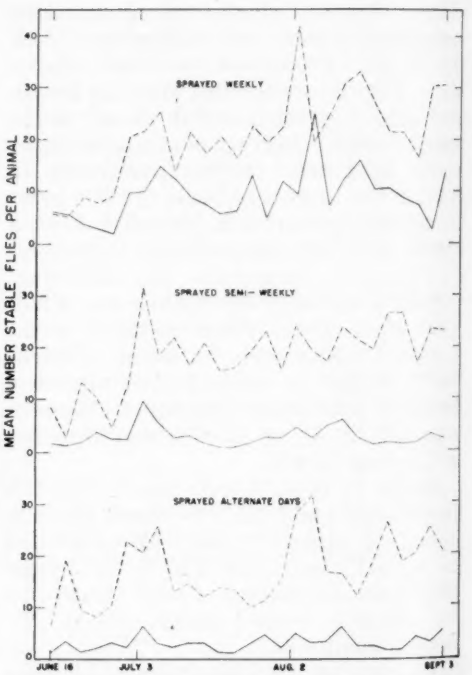

FIG. 2.—Mean number of stable flies per animal per three day period on sprayed (solid line) and unsprayed (dashes) dairy cows from July 13 to September 3, 1950 at Lincoln, Nebraska. All treatments were made with a piperonyl butoxide-pyrethrins emulsion.

herd consisted of 19 cows milked twice a day and the control herd of 4 to 6 heifers and a young bull. All herds except the control herd at dairy No. 3 had access to comparable barnyards and sudan or brome grass pasture. The control herd at dairy number 3 had access only to brome grass or sudan-rape pasture. Herds Nos. 1 and 2 at dairy No. 1 were milked in the same barn but at different times.

Herds No. 1 and 2 at dairy number 1 were sprayed daily and on alternate days respectively with a 3-gallon compressed air sprayer that delivered about 0.5 of a pint per animal. The treated herd on dairy number 2 was sprayed twice a week, Monday and Thursday, with power spray equipment operating at 150 to 200 pounds pressure and delivering 2 quarts of spray per animal. At dairy No. 3 the treated herd was sprayed once a week with the same equipment. The only formulation used was an emulsion made up the same as that used in 1949. The first treatments were applied on June 13 and the tests were concluded on September 3, 1950.

The single animal dosage for applications with the power sprayer was approximately 13.3 gram of piperonyl butoxide and 0.13 grams of pyrethrins. For applications with the compressed air sprayer the dosage was 3.3 and 0.03 gram respectively.

Fly counts and recording of limiting factors were the same as those used in 1949. Because of the increased number of counts there was an increase in the time required for sampling. All counts were made between 10:00 A.M. and 2:00 P.M. The order in which herds were sampled was rotated to prevent time of day variability in the sampling. Data collected in 1950 were analyzed statistically.

RESULTS.—Comparable results were obtained in the 1949 and 1950 tests. Figures 1 and 2 summarize fly population data for these years. Weekly animal treatments with piperonyl butoxide pyrethrins reduced the number of stable flies but did not prevent population fluctuations similar to those occurring on unsprayed animals. Comparable results were obtained with the wettable powder and emulsion formulations. Treatments applied semi-weekly, daily and on alternate days greatly reduced the number of flies and largely prevented population fluctuations. Mean fly populations for a 3 day period were used for graphic representation as the raw data for weekly and semi-weekly treatments demonstrated an average stable fly control period of 3 days.

From the data presented in figure 2 it is apparent that semi-weekly spraying was the maximum tested spacing at which fly control was effective. Population differences between sprayed and unsprayed herds for the weekly and semi-weekly treatments were highly significant. Differences between semi-weekly and alternate day and alternate day and daily treatments were not significant.

Several factors were found to affect stable fly populations on the test animals. Temperature, wind and location of the animals were the most important studied. Precipitation did not seriously affect fly numbers unless it was moderate to heavy or driven by wind. Stable fly populations on the animals were quickly reestablished following moderate to heavy rain. Table 1 summarizes 1949 data on the effects of temperature, wind and animal location on stable fly populations. Within the range of temperatures involved, 60° to 87° F., fly populations were larger under calm or light wind conditions. Larger fly populations were sustained by animals in the barnyard than by those on pasturage. Theoretical values given in the table were interpolated for purposes of comparison and are not meant to infer the possibility of predicting population levels.

DISCUSSION AND CONCLUSIONS.—The effectiveness of piperonyl butoxide-pyrethrins in controlling stable flies on dairy cows in these tests substantiates the findings of Dove (1947) and Donohoe & Cowling (1948). The latter authors, however, obtained a 5 to 7 day control period whereas only 3 dayslof fly control were obtained in these tests. As the single animal dosage applied by Donohoe & Cowling was much less than the maximum dosage used in this study it appears that unrecorded factors influence the length of the control period. Temperature, humidity and size of fly population might well be considered.

Of the spray intervals tested in this study the semi-weekly was the most efficient. The semi-weekly treatments were applied with high pressure spray equipment, however, so it is not to be inferred

that compressed air applications will give comparable results.

Ecological data accumulated during the course of this study indicate that wind, temperature and location of the animals all influence the per animal population of stable flies. Temperature and location seem to be the most important factors but additional studies should be made to establish their importance.

LITERATURE CITED

Buchmann, W. 1929. Investigations on the physiological effect of pyrethrum insect powder on fly larvae. Z. Desinfektion **21**(1, 2): 72–6.

Buchmann, W. 1929. Further investigations on the effect of pyrethrum powders on the larvae of muscids. Z. Desinfektion **21**(3): 37–9.

Cory, E. N. and N. A. Eaton. 1929. Insecticidal value of pyrethrum soaps. Md. Agr. Expt. Sta. Bul. **308**: 417–28.

Donohoe, E. L. and J. Cowling. 1948. Chemical control of cattle parasites. Agric. Chem. (3): 28–31, 74–5, 77.

Dove, Walter E. 1947. Piperonyl butoxide, a new and safe insecticide for household and field. Amer. Jour. Trop. Med. **27**(3): 339–45.

Eagleson, C. 1938. Resistance of *Stomoxys calcitrans* (L.) to laboratory application of pyrethrum spray. JOUR. ECON. ENT. **31**(6): 778.

Howard, L. O. 1926. Report of the entomologist (1925–1926). U.S.D.A.: 1–30.

Howell, D. E. and F. A. Fenton. 1944. The repellency of a pyrethrum thiocyanate oil spray to flies attacking cattle. JOUR. ECON. ENT. **37**(5): 677–80.

Lehman, Arnold J. 1948. The toxicology of the newer agricultural chemicals. Bull. Assoc. Food and Drug. Officials. U. S. **12** (3): 82–9.

Lehman Arnold J. 1950. Some toxicological reasons why certain chemicals may or may not be permitted as food additives. Bull. Assoc. Food and Drug Officials. U. S. **14**(3): 82–92.

Muma, Martin H. and Ephriam Hixson. 1949. Effects of weather, sanitation and chlorinated chemical residues on house and stable fly populations on Nebraska farms. JOUR. ECON. ENT. **42**(2): 231–8.

Wachs, Herman. 1947. Synergistic insecticides. Science **105**(2733): 530–1.

BOOK REVIEW

ATLAS OF THE SCALE INSECTS OF NORTH AMERICA, by G. F. Ferris, Volume 5, Part 1, pages i–viii, 1–288 (108 full page figures), includes less than half of the family *Pseudococcidae*, 11×8½ inches. Published by Stanford University Press, Stanford University, California. Price $7.50.

The first four volumes of the Atlas of the North American Scale Insects were devoted to the armored scales, the family Diaspididae. Each volume consists of a series of two-page, or four-page loose leaf folders, as required, devoted to each genus and each species. Each folder has a full title page, and as much additional space as needed for synonymy, hosts and distribution, technical description, notes and a full page of illustrations of each species. The last three series of Volume IV are devoted, respectfully, to classification and keys, an epilogue, and a general index to all that has preceded, making a total of 448 folders for the four volumes. These folders are available individually, or in bound volumes. The individual pages are unnumbered but the index refers to folder number.

Volume V, Part 1 is the beginning of Prof. Ferris' treatment of the mealy-bugs, family *Pseudococcidae* Some changes are noted in the editorial policy. The individual folders, referred to above for the first four volumes, have been eliminated and the pages are numbered. These changes eliminate the title page for each genus and species and save some additional pagination. A full page is devoted to each generic description; a full page or more, as required, for species descriptions, and a full page of illustrations usually facing the descriptive matter, or on the page back of it. The illustrations show the entire body of the insect with the dorsal surface features on one half and the ventral features on the other, with their approximate numbers and distribution. Around the body outline are detail drawings of the various body structures that are useful in classification. The illustrations conform to Prof. Ferris usual excellent draftmanship.

Volume V, Part 1 concerns less than half of the named species of mealy-bugs from North America, which is considered to be Panama and northward, including the Greater Antilles. In all, 21 genera, 12 of them described as new, and 103 species are treated. The appearance of Part 1 represents beginning of the first revisional study of North American mealy-bugs. Numerous species have been described and many of them assigned to a few of the more common genera, sometimes without due regard for the limitations imposed by genotypes. The breaking up of these large assemblages of species involves the changing of generic names of some species where long bibliographies have accumulated on account of their importance as economic pests. As an example, the wide spread citrus mealy-bug *Pseudococcus citri* (Risso) becomes *Planococus citri* (Risso). There are other changes of generic names of important species that may cause some temporary inconvenience, but such changes are inevitable.

The arrangement of the material in this volume is such as to facilitate its usefulness to entomologists. Preliminary sections deal with the morphological features that are used in classification to assist workers in making identifications of this economically important group of scale insects. It will no doubt serve to stimulate more entomologists to become familiar with the taxonomy of the mealy-bugs.

H. S. MCCONNELL

The Insecticidal Properties of Some Esters of Phosphorus Acids[1,2,3]

G. F. Ludvik[4] and G. C. Decker, *Illinois Natural History Survey and Illinois Agricultural Experiment Station, Urbana*

In an earlier paper, Ludvik & Decker (1947) reported the results obtained with 46 phosphorus acid esters against two species of aphids, *Myzus persicae* Sulzer and *M. porosus* Sanderson and showed that tetraethyl pyrophosphate and tetrapropyl pyrophosphate were about four times as toxic as hexaethyl tetraphosphate to these insects. The present study greatly extends the scope of the earlier work in number of compounds tested, in number of species of test insects utilized, and in the variety of methods employed in these evaluations.

Schrader (1947) prepared tetraethyl pyrophosphate and investigated its insecticidal properties, but his results were not released by the British Intelligence Objectives Sub-Committee until after the work of Ludvik & Decker had appeared. Subsequently, Hansen (1947) and Hall & Jacobson (1948) reported that tetraethyl pyrophosphate is the active ingredient present in hexaethyl tetraphosphate. Early reports on hexaethyl tetraphosphate stressed the fact that the material is highly toxic to higher animals as well as to insects, and that due care and caution should be exercised when it is used or handled (Rohwer 1947; Krop 1948; Lehman 1948). Roeder (1948) and others have shown that the effectiveness of the several organic phosphate esters is due to their inhibition of the enzyme cholinesterase.

Experimental Procedures.—Cultures of the green peach aphid, *Myzus persicae*, were maintained on potted eggplants grown in the greenhouse. Individual leaves infested with 100 to 200 aphids of various stages of development were cut from the plants and sprayed. The stem of the sprayed leaf was inserted through a paper disc, wrapped in cotton, and set into a small bottle of water. The unit was then placed within a heated wire barrier to prevent the loss of unaffected aphids (Bruce 1947).

Cultures of the aphid, *Myzus porosus*, were maintained on potted rose plants grown in the greenhouse. Individual leaves infested with approximately 100 aphids of various stages of development were cut from the plants and sprayed. The petiole of a sprayed leaf was trimmed and inserted into the tube of a watering vial, according to the method described by Kearns and Compton (1938), and the unit placed within a heated wire barrier.

Five day old adults of the standard NAIDM strain of the house fly, *Musca domestica* L., were used in the present work. The rearing procedure was that described for the Peet-Grady method in Soap Blue Book (1946).

Larvae of the black carpet beetle, *Attagenus piceus* Oliv., were reared in the laboratory in a medium consisting of 2 per cent dried brewers' yeast in chick starter mash. Larvae about three-eighths of an inch in length were selected for testing.

Myzus persicae, *M. porosus*, and *Musca domestica* were used as test insects for determining the effects of the chemicals as contact sprays. An atomizer-type, compressed-air paint sprayer of 1-pint capacity, operating at a pressure of 30 pounds per square inch, was used to spray excised leaves infested with either *Myzus persicae* or *M. porosus*. Solutions were prepared by pipetting 0.1 milliliter of chemical into a measured volume of stock solution containing one gram of sodium decylbenzenesulfonate (*Santomerse D*) per 5 liters of distilled water. Water-insoluble liquids were thoroughly shaken in a graduated cylinder to obtain a homogeneous emulsion and sprayed as rapidly as possible so that a uniform spray would result. Weighed quantities of solid chemicals were dissolved in a known volume of dioxane, and their subsequent water mixtures were handled in the manner described for water-insoluble liquid com-

[1] The data presented are from a thesis submitted by the senior author to the Graduate School of the University of Illinois in partial fulfilment of the requirements for the Ph.D. degree in Entomology.

[2] This investigation was sponsored by the Monsanto Chemical Company of St. Louis, Missouri, who prepared and supplied most of the compounds for these tests.

[3] Costs paid to secure early publication.

[4] Present address: Malaria Control Branch, Tennessee Valley Authority, Wilson Dam, Alabama.

pounds. In the case of *M. persicae*, tests were made only at a concentration of 0.2 per cent, whereas with *M. porosus*, sufficient subsequent dilutions were made to determine the minimum range of effectiveness of the chemical under consideration.

Contact spray tests against adult house flies were carried out in accordance with the small-chamber method developed by Kearns & March (1943). All materials were tested at a concentration of one per cent by weight in 50 per cent benzene—50 per cent mineral seal oil or in 50 per cent benzene—50 per cent methyl alcohol, depending upon the solubilities of the chemicals. Chemicals which exhibited toxicity were tested at lower concentrations to determine the range of their effectiveness. Each contact spray test was run five times.

Tests for residual activity were made by exposing five-day-old adult house flies for 30 minutes to deposits on glass of 50 milligrams of chemical per square foot of surface area. The flies were reared as described for the contact spray tests, but the puparia were placed in 7.5 by 7.5 by 1.25-inch wooden cages having screen tops and sliding metal bottoms. The sliding bottom facilitated removal of the empty puparia and also allowed the flies to have free access to the treated surface during the period of exposure. For exposure, the cage was inverted and covered with a glass plate with the treated surface down. These units were stacked 10 high and the metal slides pulled out for 30 minutes. The treated surface was prepared by pipetting 2 milliliters of a solution containing 12.5 milligrams of chemical per milliliter of absolute ethyl alcohol on a 72-square-inch area of a 9-inch-square glass plate. The solution was spread over the surface as evenly as possible with a small piece of glass. Three replicates of each solution were prepared.

For carpet-beetle tests circles of wool 2 square inches in area were treated with 1 milliliter of the solution used for the preparation of the glass plates. After the alcohol had evaporated from the wool, the circles were placed in 35 by 50-millimeter crystallizing dishes and manually infested with 10 *Attagenus piceus* (Oliv.) larvae (Fletcher 1943). When all 10 larvae were killed by a particular chemical, ten more larvae were placed on the wool. Three wool circles were prepared for each chemical.

Observations on mortality for all insects except *Attagenus piceus* were made the day after treatments or exposures were completed.

EXPERIMENTAL RESULTS.—In so far as possible, all chemicals were tested as contact sprays against the green peach aphid, *Myzus persicae*, and the house fly, *Musca domestica*. Chemicals which exhibited marked insecticidal activities against these two species were subsequently tested to determine the susceptibilities of different species, to establish toxicity ranges, and to investigate residual activities.

Certain data from the work of Ludvik & Decker (1947) are included in the presentation of the results of the present study to facilitate the comparison of toxicities, since certain compounds tested by them were later evaluated against another insect species.

A double-distilled sample of tetraethyl pyrophosphate was used in the present work instead of the sample of unknown purity used earlier.

The results of this investigation are presented in tables 1 to 5.

DISCUSSION.—In general, the results of the tests against *Myzus persicae* revealed minor differences in toxicity among the various chemicals. Tests against the house fly were essentially quantal at the 1 per cent concentration, and minor differences in toxicity were not apparent. By the methods used, the house fly was found to be more resistant to this series of chemicals than were *Myzus porosus* and *M. persicae*. Tests against *M. porosus* and *Musca domestica* showed diethyl *p*-nitrophenyl phosphate to be more toxic than diethyl *p*-nitrophenyl thionophosphate, which in turn proved to be more toxic than tetraethyl pyrophosphate. Although residues on glass plates of several of the more toxic compounds gave high kills of house flies 2 hours after the plates were prepared, only three compounds exhibited a prolonged residual activity. These were diethyl *p*-nitrophenyl phosphate, diethyl *o*-nitrophenyl phosphate, and diethyl *p*-nitrophenyl thionophosphate. The relatively high volatility or rapid hydrolysis of most of these compounds is assumed to explain their lack of residual activity.

Table 1.—Toxicity of certain phosphorus acid esters applied as contact sprays to *Myzus persicae*, *M. porosus*, and *Musca domestica*.

Compound		Per Cent Kill		
		Myzus[1] *persicae*	*Myzus*[1] *porosus*	*Musca*[2] *domestica*
Alkyl Acid Phosphate Esters: $((HO)_2P(O)OR$ and $HOP(O)(OR)_2)$[3]				
Methyl	$R=CH_3$	51.4*[4]		1.3 (m)[5]
Ethyl	$R=C_2H_5$	37.8*		3.2 (m)
Propyl	$R=C_3H_7$	55.1*		1.7 (m)
Isopropyl	$R=(CH_3)_2CH$	73.6*	46.5*	3.4 (m)
Butyl	$R=C_4H_9$	62.2*		4.6 (m)
Isoamyl	R = mixed primary C_5H_{11}	56.6*		3.2 (m)
Octyl	$R=C_8H_{17}$	79.4*	66.0*	9.3
Decyl	$R=C_{10}H_{21}$	65.9*		6.0 (m)
Loralkyl	R = mixture of 10 to 18 carbon chains	4.5*		8.3
Dialkyl Acid Phosphate Esters: $(HOP(O)(OR)_2)$				
Diethyl	$R=C_2H_5$	13.4		4.1 (m)
Diethyl thionothio[6]	$R=C_2H_5$	17.2		6.7
Dibutyl	$R=C_4H_9$	22.4		7.8
Trialkyl and Triaryl Phosphate Esters: $((RO)_3PO)$				
Trimethyl	$R=CH_3$	52.2*		5.3
Triethyl	$R=C_2H_5$	14.7*		4.9
Triethyl thiono	$R=C_2H_5$	17.7		0.2
Tri-(2-chloroethyl)	$R=ClC_2H_4$	45.6*		9.4
Tripropyl	$R=C_3H_7$	22.2		5.1
Triallyl	$R=CH_2=CHCH_2$	28.8*		9.9
Trimethallyl	$R=CH_2=C(CH_3)CH_2$	33.9*		2.0 (m)
Tri-(2,3-dichloropropyl)	$R=ClCH_2CH(Cl)CH_2$	3.5		4.2
Tributyl	$R=C_4H_9$	59.8		6.0
Triisobutyl	$R=(CH_3)_2CHCH_2$	23.7		8.8
Triamyl	$R=C_5H_{11}$	66.6		7.0
Triisoamyl	$R=(CH_3)_2CH(CH_2)_2$	66.0		6.8
Tri-(2-methylamyl)	$R=C_3H_7CH(CH_3)CH_2$	90.2		9.9
Tri-(2-ethylhexyl)	$R=C_4H_9CH(C_2H_5)CH_2$	87.1*	51.1*	4.1
Tridodecyl	$R=C_{12}H_{25}$	41.8		3.7 (m)
Triphenyl	$R=C_6H_5$	21.2*		3.3
Tricresyl	$R=CH_3C_6H_4$	20.3*		6.6
Tri-(*o*-chlorophenyl)	$R=ClC_6H_4$	5.3*		4.2
Tri-(2,4,6-trichlorophenyl)	$R=Cl_3C_6H_2$	8.2*		2.6 (m)
Mixed Phosphate Esters: $((RO)_2P(O)OR')$				
Diethyl octyl	$R=C_2H_5$			
	$R'=C_8H_{17}$	97.7	98.9	99.0
Acetyl diethyl	$R=C_2H_5$			
	$R'=CH_3CO$	100.0		
Diethyl phenyl	$R=C_2H_5$			
	$R'=C_6H_5$	99.1	9.8	39.8
Diethyl phenyl thiono	$R=C_2H_5$			
	$R'=C_6H_5$	30.9		5.0
Diethyl *p*-nitrophenyl thiono	$R=C_2H_5$			
	$R'=O_2NC_6H_4$	99.8		
Benzyl diethyl	$R=C_2H_5$			
	$R'=C_6H_4CH_2$	24.3		11.7
Di-(2-chloroethyl) Loralkyl	$R=ClC_2H_4$			
	R' = mixture of 10 to 18 carbon chains	40.8		9.7
Dibutyl ethyl	$R=C_4H_9$			
Mixed butyl 2-ethylhexyl	$R'=C_2H_5$	55.1		6.7
Dibutyl phenyl	$R=C_4H_9$	95.0		5.5
	$R'=C_6H_5$	58.7		2.3
Di-(2-ethylhexyl) phenyl	$R=C_4H_9CH(C_2H_5)CH_2$			
	$R'=C_6H_5$	80.5		1.4
Methyl diphenyl	$R=C_6H_5$			
	$R'=CH_3$	70.0		11.5

Compound		Per Cent Kill		
		Myzus[1] *persicae*	*Myzus*[1] *porosus*	*Musca*[2] *domestica*
Ethyl diphenyl	$R = C_6H_5$ $R' = C_2H_5$	27.0		1.2
2-Methoxyethyl diphenyl	$R = C_6H_5$ $R' = CH_2OC_2H_4$	17.9		5.4
2-Butoxyethyl diphenyl	$R = C_6H_5$ $R' = C_4H_9OC_2H_4$	39.1		5.0
Butyl diphenyl	$R = C_6H_5$ $R' = C_4H_9$	49.1		1.2
5-Butoxyamyl diphenyl	$R = C_6H_5$ $R' = C_4H_9OC_5H_{10}$	48.0		6.0
6-Methylheptyl diphenyl	$R = C_6H_5$ $R' = (CH_3)_2CH(CH_2)_5$	62.1		8.7
Nonyl diphenyl	$R = C_6H_5$ $R' = C_9H_{19}$	74.8		6.0
Decyl diphenyl	$R = C_6H_5$ $R' = C_{10}H_{21}$	59.8		5.9
Decyl diphenyl	$R = C_6H_5$ $R' =$ branched $C_{10}H_{21}$	62.7		4.5
Cyclohexyl diphenyl	$R = C_6H_5$ $R' = C_6H_{11}$	26.2		3.8
Cresyl diphenyl	$R = C_6H_5$ $R' = CH_3C_6H_4$	8.3		8.7
p-tert. Butylphenyl diphenyl	$R = C_6H_5$ $R' = (CH_3)_3CC_6H_4$	7.4		3.7
p-tert. Amylphenyl diphenyl	$R = C_6H_5$ $R' = C_2H_5C(CH_3)_2C_6H_4$	10.0		10.0
o-Chlorophenyl diphenyl	$R = C_6H_5$ $R' = ClC_6H_4$	6.6		5.1
Diphenyl *o*-xenyl	$R = C_6H_5$ $R' = C_6H_5C_6H_4$	6.0		6.4
Butyl dicresyl	$R = CH_3C_6H_4$ $R' = C_4H_9$	49.2		4.8
Dicresyl 2-ethylhexyl	$R = CH_3C_6H_4$ $R' = C_4H_9CH(C_2H_5)CH_2$	30.9		4.8
Phosphonate Esters: $((RO)_2P(O)R')$				
Diethyl trichloromethane-	$R = C_2H_5$ $R' = Cl_3C$	28.1*		11.3
Triethyl phosphonoacetate	$R = C_2H_5$ $R' = C_2H_5OOCCH_2$	55.4*		10.)
Diethyl *p*-chlorobenzene-	$R = C_2H_5$ $R' = ClC_6H_4$	55.0*		8.2
Diethyl 3,4-dichlorobenzene-	$R = C_2H_5$ $R' = Cl_2C_6H_3$	66.8*		7.4
Di-(2-chloroethyl)2-chloroethane-	$R = R' = ClC_2H_4$	20.7		7.9
Dibutyl trichloromethane-	$R = C_4H_9$ $R' = Cl_3C$	24.3*		12.4
Dibutyl 2-propene-1-	$R = C_4H_9$ $R' = CH_2=CHCH_2$-	70.9*		9.8
Dibutyl 2-methyl-2-propene-1-	$R = C_4H_9$ $R' = CH_2=C(CH_3)CH_2$-	76.1*		4.3
Dibutyl β-styrene-	$R = C_4H_9$ $R' = C_6H_5CH=CH$	90.3*	38.7*	10.7
Di-(2-ethylhexyl) benzene-	$R = C_4H_9CH(C_2H_5)CH_2$ $R' = C_6H_5$	94.8		5.8
Di-(2-ethylhexyl) toluene-	$R = C_4H_9CH(C_2H_5)CH_2$ $R' = CH_3C_6H_4$	95.5		3.7
Di-(2-ethylhexyl) ethylbenzene-	$R = C_4H_9CH(C_2H_5)CH_2$ $R' = C_2H_5C_6H_4$	85.6		5.5

COMPOUND		PER CENT KILL		
		Myzus[1] *persicae*	*Myzus*[1] *porosus*	*Musca*[2] *domestica*
Di-(2-ethylhexyl) *p*-chlorobenzene-	$R = C_4H_9CH(C_2H_5)CH_2$ $R' = ClC_6H_4$	83.4		3.7
Di-(2-ethylhexyl) α-toluene-	$R = C_4H_9CH(C_2H_5)CH_2$ $R' = C_6H_5CH_2$-	96.9		4.7
Di-(*p*-chlorophenyl) ethane-	$R = ClC_6H_4$ $R' = C_2H_5$	26.2*		11.5
Dialkyl Phosphite Esters: $((RO)_2POH)$				
Diethyl	$R = C_2H_5$	12.2*		1.4 (m)
Di-(2-cyanoethyl)	$R = NCC_2H_4$	12.0		
Dipropyl	$R = C_3H_7$	20.4		1.2
Dibutyl	$R = C_4H_9$	23.8*		5.3
Trialkyl and Triaryl Phosphite Esters: $(P(OR)_3)$				
Triethyl	$R = C_2H_5$	13.7*		10.3
Tributyl	$R = C_4H_9$	30.6*		3.1 (m)
Tricyclohexyl	$R = C_6H_{11}$	8.4		4.6
Triphenyl	$R = C_6H_5$	63.8		7.2
Tricresyl	$R = CH_3C_6H_4$	63.3		7.6
Alkyl- and Arylphosphonic Acids: $((HO)_2P(O)R)$				
α-Toluene	$R = C_6H_5CH_2$	5.3		2.3 (m)
(Diphenylmethane)	$R = (C_6H_5)_2CH$			2.8 (m)
Butane	$R = C_4H_9$			0.8 (m)
Pentane	$R = C_5H_{11}$			1.4 (m)
Hexane	$R = C_6H_{13}$			1.0 (m)
p-Chlorobenzene	$R = ClC_6H_4$	6.1*		6.8 (m)
3,4-Dichlorobenzene	$R = Cl_2C_6H_3$	4.8*		9.3 (m)
Tetraalkyl Pyrophosphate and Related Esters: $((RO)_2P(O)OP(O)(OR)_2)$				
Ethyl butanephosphonodiethoxyphosphine oxide, $C_2H_5O(C_4H_9)P(O)OP(O)(OC_2H_5)_2$				29.2
Ethyl 2-ethylhexanephosphonodiethoxyphosphine oxide, $C_2H_5O(C_4H_9CH(C_2H_5)CH_2)P(O)OP(O)(OC_2H_5)_2$		100.0	20.4	18.5
Ethyl *p*-chlorobenzenephosphonodiethoxyphosphine oxide, $C_2H_5O(ClC_6H_4)P(O)OP(O)(OC_2H_5)_2$				83.8
unsym. Diethyl diphenyl pyrophosphate, $(C_2H_5O)_2P(O)OP(O)(OC_6H_5)_2$				68.7
Tetrabutyl	$R = C_4H_9$			97.6
Tributyl ethyl pyrophosphate, $C_2H_5O(C_4H_9O)P(O)OP(O)(OC_4H_9)_2$				91.9
Butyl butanephosphonoethoxybutoxyphosphine oxide, $C_4H_9O(C_4H_9)P(O)OP(O)(OC_2H_5)OC_4H_9$				81.0
Octamethyltetraamidopyrophosphate, $((CH_3)_2N)_2P(O)OP(O)(N(CH_3)_2)_2$		99.1		12.0
Diethoxyphosphino ethyl acid phosphate, $(C_2H_5O)_2POP(O)(OH)OC_2H_5$			98.4	9.7 (m)
Alkyl Amidophosphate Esters:				
Hexamethylphosphoramide, $((CH_3)_2N)_3PO$		10.5		6.7
Ethyl tetramethyldiamidophosphate, $C_2H_5OP(O)(N(CH_3)_2)_2$		5.0		2.6
Diethyl N,N-dimethylamidophosphate, $(C_2H_5O)_2P(O)N(CH_3)_2$		9.1		3.1
Diethyl N-ethylamidophosphate, $(C_2H_5O)_2P(O)NHC_2H_5$		8.7		3.3
Bis(2-methoxyethyl) N,N-diethylamidophosphate, $(CH_3OC_2H_4O)_2P(O)N(C_2H_5)_2$		6.3		4.4
Tetraalkyl Aryl Triphosphate Esters: $((RO)_2P(O)OP(O)(OR')OP(O)(OR)_2)$				
Phenyl tetrapropyl	$R = C_3H_7$ $R' = C_6H_5$			24.1
p-Cresyl tetrapropyl	$R = C_3H_7$ $R' = CH_3C_6H_4$	9.5		3.5

COMPOUND	PER CENT KILL		
	Myzus[1] *persicae*	*Myzus*[1] *porosus*	*Musca*[2] *domestica*
Miscellaneous Compounds:			
Ethyl metaphosphate, $C_2H_5OP(O)O$		87.8	69.4 (m)
Poly-(dibutoxyphosphonitrile), $(N{\equiv}P(OC_4H_9)_2)_x$	48.7*		4.9
Diethylene glycol bis(diphenyl phosphate), $((C_6H_5O)_2P(O)OC_2H_4)_2O$	33.8*		3.5
Di-(cyclohexylamino)phosphonitrile, $N{\equiv}P(NHC_6H_{11})_2$			3.1
Triphenyl phosphine, $(C_6H_5)_3P$	31.6		6.6
Tri-(*p*-chlorophenyl)phosphine oxide, $(ClC_6H_4)_3PO$	13.4*		4.7
Triphenylphosphine sulfide, $(C_6H_5)_3PS$			5.9
Difference required for significance at the five per cent level	28.8	9.4	8.2
50% Benzene-50% mineral seal oil			2.3[7]
50% Benzene-50% methyl alcohol			2.6[8]
Sodium decylbenzenesulfonate at 0.02%	7.1[9]	7.1[10]	
Nicotine, 99%, at 0.05%	42.4[9]	44.1[10]	

[1] At concentrations of 0.2 per cent.
[2] At concentrations of one per cent.
[3] Commercial products containing a constant ratio of the di- to the mono-ester.
[4] * indicates data from Ludvik and Decker (1947).
[5] (m) indicates that the compound was soluble in 50% benzene-50% methyl alcohol.
[6] Obtained from Victor Chemical Works, Chicago, Illinois.
[7] Average of 143 tests.
[8] Average of 25 tests.
[9] Average of 31 tests.
[10] Average of 37 tests.

Table 2.—Toxicity of certain phorphorus acid esters applied as contact sprays to *Myzus porosus*.

COMPOUND	PER CENT KILL AT PARTS PER MILLION CONCENTRATION									
	1000	500	200	100	50	25	12.5	6.25	3.13	1.56
Mixed Alkyl and Acyl-Alkyl Phosphate Esters: $((RO)_2P(O)OR')$										
Diethyl octyl $R=C_2H_5$ $R'=C_8H_{17}$	95.7	91.5	56.0							
Acetyl diethyl $R=C_2H_5$ $R'=CH_3CO$		92.3	60.7	31.5	10.0					
Dialkyl Aryl Phosphate Esters: $((RO)_2P(O)OR')$										
Diethyl *o*-nitrophenyl[1] $R=C_2H_5$ $R'=O_2NC_6H_4$		97.9	93.7	68.2	33.6					
Diethyl *p*-nitrophenyl[1] $R=C_2H_5$ $R'=O_2NC_6H_4$							99.4	94.1	84.9	48.1
Diethyl *p*-nitrophenyl thiono $R=C_2H_5$ $R'=O_2NC_6H_4$						99.5	93.0	76.6	47.5	
Tetraalkyl Pyrophosphate and Related Esters: $((RO)_2P(O)OP(O)(OR)_2)$										
Tetraethyl $R=C_2H_5$				97.4	97.2	95.8	74.5	32.1	15.0	
Tetraethyl monothiono $R=C_2H_5$					99.0	71.0	36.6	11.4		
Ethyl methanephosphonodiethoxyphosphine oxide, $C_2H_5O(CH_3)P(O)OP(O)(OC_2H_5)_2$			96.2	89.6	80.8	60.9				
Ethyl ethanephosphonodiethoxyphosphine oxide, $C_2H_5O(C_2H_5)P(O)OP(O)(OC_2H_5)_2$				98.9	88.0	74.7	35.8	17.8		
Ethyl butanephosphonodiethoxyphosphine oxide, $C_2H_5O(C_4H_9)P(O)OP(O)(OC_2H_5)_2$	81.4	60.7	27.2							
Ethyl benzenephosphonodiethoxyphosphine oxide, $C_2H_5O(C_6H_5)P(O)OP(O)(OC_2H_5)_2$			94.5	70.6	53.5	29.6				
Ethyl *p*-chlorobenzenephosphonodiethoxyphosphine oxide,										

COMPOUND	PER CENT KILL AT PARTS PER MILLION CONCENTRATION									
	1000	500	200	100	50	25	12.5	6.25	3.13	1.56
$C_2H_5O(ClC_6H_4)P(O)OP(O)(OC_2H_5)_2$			88.3	79.1	51.4	48.7				
unsym. Dibutyl diethyl pyrophosphate, $(C_2H_5O)_2P(O)OP(O)(OC_4H_9)_2$					99.0	97.0	74.2	40.2	15.1	
unsym. Diethyl di-(2-ethylhexyl) pyrophosphate, $(C_2H_5O)_2P(O)OP(O)(OCH_2CH(C_2H_5)C_4H_9)_2$				99.5	73.9	35.1	14.3			
unsym. Diethyl diphenyl pyrophosphate, $(C_2H_5O)_2P(O)OP(O)(OC_6H_5)_2$				97.6	87.9	71.8	44.8	11.1		
Tetrapropyl[2] R = C_3H_7				91.6	75.4	50.9				
Tetraisopropyl R = $(CH_3)_2CH$						95.8	69.6	60.3	21.3	
Di-(isopropoxy)phosphino diisopropyl phosphate, $((CH_3)_2CHO)_2POP(O)(OCH(CH_3)_2)_2$				97.9	90.2	65.6	48.3	30.8		
Tetrabutyl R = C_4H_9				99.5	81.6	50.8	11.8			
Tributyl ethyl pyrophosphate, $C_2H_5O(C_4H_9O)P(O)OP(O)(OC_4H_9)_2$		100.0	84.3	71.8						
Butyl butanephosphonoethoxybutoxyphosphine oxide, $C_4H_9O(C_4H_9)P(O)OP(O)(OC_2H_5)OC_4H_9$	97.6	95.4	89.9	68.3	24.8					
Diethoxyphosphino ethyl acid phosphate, $(C_2H_5O)_2POP(O)(OH)OC_2H_5$	92.7	72.8	20.5							
Tetraalkyl Aryl Triphosphate Ester: $((RO)_2P(O)OP(O)(OR')OP(O)(OR)_2)$										
Phenyl tetrapropyl R = C_3H_7 R′ = C_6H_5			99.5	85.9[2]	66.4[2]	16.3				
Alkyl Metaphosphate Ester: $(ROP(O)O)$										
Ethyl R = C_2H_5	79.8	68.3	32.2							
Difference required for significance at the five per cent level	14.1	19.4	19.7	16.4	18.4	22.4	18.6	13.7	14.8	

[1] Obtained from Victor Chemical Works, Chicago, Illinois. [2] Data from Ludvik and Decker (1947).

Table 3.—Toxicity of certain phorphorus acid esters applied as contact sprays to *Musca domestica*.

COMPOUND	PER CENT KILL AT PARTS PER MILLION CONCENTRATION									
	5000	2500	1250	625	313	156	78	39	18.5	9.25
Mixed Alkyl and Acyl-Alkyl Phosphate Esters: $((RO)_2P(O)OR')$										
Diethyl octyl R = C_2H_5 R′ = C_8H_{17}	85.0	39.7								
Acetyl diethyl R = C_2H_5 R′ = CH_3CO	99.8	96.4	73.8	33.7						
Dialkyl Aryl Phosphate Esters: $((RO)_2P(O)OR')$										
Diethyl *o*-nitrophenyl R = C_2H_5 R′ = $O_2NC_6H_4$			99.8	98.3	75.9	84.3	54.2	11.5		
Diethyl *p*-nitrophenyl R = C_2H_5 R′ = $O_2NC_6H_4$					100.0	99.8	97.6	71.4	35.7	8.2
Diethyl *p*-nitrophenyl thiono R = C_2H_5 R′ = $O_2NC_6H_4$					99.1	99.7	83.4	36.0	21.4	
Tetraalkyl Pyrophosphate and Related Esters: $((RO)_2P(O)OP(O)(OR)_2)$										
Tetraethyl R = C_2H_5			99.2	97.9	93.1	82.1	51.2	42.0		

Compound	Per Cent Kill at Parts per Million Concentration									
	5000	2500	1250	625	313	156	78	39	18.5	9.25
Tetraethyl monothiono										
R = C_2H_5				95.9	91.7	47.7				
Ethyl methanephosphonodiethoxyphosphine oxide, $C_2H_5O(CH_3)P(O)OP(O)(OC_2H_5)_2$	96.3	91.6	70.7	21.5						
Ethyl ethanephosphonodiethoxyphosphine oxide, $C_2H_5O(C_2H_5)P(O)OP(O)(OC_2H_5)_2$	94.8	96.0	29.5							
Ethyl butanephosphonodiethoxyphosphine oxide, $C_2H_5O(C_4H_9)P(O)OP(O)(OC_2H_5)_2$	20.2	11.4								
Ethyl benzenephosphonodiethoxyphosphine oxide, $C_2H_5O(C_6H_5)P(O)OP(O)(OC_2H_5)_2$	97.4	86.9	50.8	33.5						
Ethyl *p*-chlorobenzenephosphonodiethoxyphosphine oxide, $C_2H_5O(ClC_6H_4)P(O)OP(O)(OC_2H_5)_2$	73.1	44.1	30.1							
unsym. Dibutyl diethyl pyrophosphate, $(C_2H_5O)_2P(O)OP(O)(OC_4H_9)_2$		100.0	95.2	87.4	63.4	43.8				
unsym. Diethyl di-(2-ethylhexyl) pyrophosphate, $(C_2H_5O)_2P(O)OP(O)(OCH_2CH(C_2H_5)C_4H_9)_2$	99.6	81.7	51.8	28.5						
unsym. Diethyl diphenyl pyrophosphate, $(C_2H_5O)_2P(O)OP(O)(OC_6H_5)_2$	35.7									
Tetrapropyl R = C_3H_7			93.8	79.7	51.4	19.4				
Tetraisopropyl R = $(CH_3)_2CH$						96.0	84.0	42.0	23.5	
Di-(isopropoxy)phosphino diisopropyl phosphat, $((CH_3)_2CHO)_2POP(O)(OCH(CH_3)_2)_2$			99.6	90.6	58.3	29.9				
Tetrabutyl R = C_4H_9	90.4	58.4	22.1							
Tributyl ethyl pyrophosphate, $C_2H_5O(C_4H_9O)P(O)OP(O)(OC_4H_9)_2$	61.4	41.1	17.1							
Butyl butanephosphonoethoxybutoxyphosphine oxide, $C_4H_9O(C_4H_9)P(O)OP(O)(OC_2H_5)OC_4H_9$	76.2	58.6								
Alkyl Metaphosphate Ester: (ROP(O)O)										
Ethyl R = C_2H_5	17.5									
Difference required for significance at the five per cent level	19.1	20.9	9.8	28.8	14.0	22.0	28.2	34.2		

The following compounds were most effective, in the order enumerated, in protecting wool from damage by black carpet beetle larvae: diethyl *p*-nitrophenyl phosphate, diethyl *p*-nitrophenyl thionophosphate, tetraisopropyl pyrophosphate, diethyl *o*-nitrophenyl phosphate, tetraethyl monothionopyrophosphate, diethyl octyl phosphate, and tetraethyl pyrophosphate.

INSECTICIDAL PROPERTIES OF THE SEVERAL GROUPS OF ESTERS STUDIED.—As a group, the alkyl acid phosphate esters tested are non toxic to aphids and the house fly. As Kearns & Flint (1937) have previously shown with other homologous series, the toxicity within the group rises as the number of carbon atoms in the aliphatic chain is increased. Maximum toxicity is reached with the eight carbon chain, with further increases in length producing lower toxicity. This trend is apparent, but significant only between the ethyl and the octyl derivatives, in the results obtained against *Myzus persicae*. No support for this trend can be gained from the results obtained against *Musca domestica*.

The dialkyl acid phosphates are likewise non toxic to aphids and the house fly, though the trend of the results against both insects indicates that a similar relationship exists between length of carbon chain and toxicity. The differences in the results obtained from the

three compounds tested, however, are too small to permit a valid conclusion to be drawn.

Two compounds in the series of trialkyl phosphate esters studied exhibit considerable toxicity to *Myzus persicae* but are non toxic to *Musca domestica*. They are the 2-methylamyl and the 2-ethyl-hexyl derivatives. The 2, 3, 4, 5, and 12 carbon atom, straight-chain derivatives were available for study in this group. Here again there is a trend toward maximum

Table 4.—24 hour mortality of *Musca domestica* following exposure to aged treated surfaces.

Compound		Age of Surface		
		Two Hours	Five Days	Ten Days
Mixed Alkyl and Acyl-Alkyl Phosphate Esters: $((RO)_2P(O)OR')$				
Diethyl octyl	$R = C_2H_5$, $R' = C_8H_{17}$	62.7	7.4	
Acetyl diethyl	$R = C_2H_5$, $R' = CH_3CO$	54.4	4.8	
Dialkyl Aryl Phosphate Esters: $((RO)_2P(O)OR')$				
Diethyl phenyl	$R = C_2H_5$, $R' = C_6H_5$	2.2		
Diethyl *o*-nitrophenyl	$R = C_2H_5$, $R' = O_2NC_6H_4$	99.4	95.7	86.4[1]
Diethyl *p*-nitrophenyl	$R = C_2H_5$, $R' = O_2NC_6H_4$	100.0	100.0	100.0[2]
Diethyl *p*-nitrophenyl thiono	$R = C_2H_5$, $R' = O_2NC_6H_4$	100.0	100.0	100.0[3]
Tetraalkyl Pyrophosphate and Related Esters: $((RO)_2P(O)OP(O)(OR)_2)$				
Tetraethyl	$R = C_2H_5$	97.5	2.2	
Tetraethyl monothiono	$R = C_2H_5$	100.0	2.6	
Ethyl methanephosphonodiethoxyphosphine oxide, $C_2H_5O(CH_3)P(O)OP(O)(OC_2H_5)_2$		61.6	1.4	
Ethyl ethanephosphonodiethoxyphosphine oxide, $C_2H_5O(C_2H_5)P(O)OP(O)(OC_2H_5)_2$		68.8	0.9	
Ethyl butanephosphonodiethoxyphosphine oxide, $C_2H_5O(C_4H_9)P(O)OP(O)(OC_2H_5)_2$		0.4		
Ethyl benzenephosphonodiethoxyphosphine oxide, $C_2H_5O(C_6H_5)P(O)OP(O)(OC_2H_5)_2$		72.8	3.1	
Ethyl *p*-chlorobenzenephosphonodiethoxy phosphine oxide, $C_2H_5O(ClC_6H_4)P(O)OP(O)(OC_2H_5)_2$		72.3	1.0	
unsym. Dibutyl diethyl pyrophosphate, $(C_2H_5O)_2P(O)OP(O)(OC_4H_9)_2$		92.7	3.5	
unsym. Diethyl di-(2-ethylhexyl) pyrophosphate, $(C_2H_5O)_2P(O)OP(O)(OCH_2CH(C_2H_5)C_4H_9$		81.3	2.8	
unsym. Diethyl diphenyl pyrophosphate, $(C_2H_5O)_2P(O)OP(O)(OC_6H_5)_2$		95.2	3.0	
Tetrapropyl	$R = C_3H_7$	98.2	3.5	
Tetraisopropyl	$R = (CH_3)_2CH$	100.0	74.0	1.2
Di-(isopropoxy)phosphino diisopropyl phosphate, $((CH_3)_2CHO)_2POP(O)(OCH(CH_3)_2)_2$		22.6	3.1	
Tetrabutyl	$R = C_4H_9$	97.8	0.7	
Tributyl ethyl pyrophosphate, $C_2H_5O(C_4H_9O)P(O)OP(O)(OC_4H_9)_2$		78.6	2.0	
Butyl butanephosphonoethoxybutoxyphosphine oxide, $C_4H_9O(C_4H_9)P(O)OP(O)(OC_2H_5)OC_4H_9$		65.6	2.2	
Diethoxyphosphino ethyl acid phosphate, $(C_2H_5O)POP(O)(OH)OC_2H_5$		0.0		
Tetraalkyl Aryl Triphosphate Ester: $((RO)_2P(O)OP(O)(OR')OP(O)(OR)_2)$				
Phenyl tetrapropyl	$R = C_3H_7$, $R' = C_6H_5$	0.8		
Alkyl Metaphosphate Ester: (ROP(O)O)				
Ethyl	$R = C_2H_5$	34.2	2.8	
Ethyl Alcohol, Absolute		0.0	0.7	0.6
Untreated Glass		0.7	0.8	1.1

[1] 62% kill after 23 days, and 20% kill after 37 days.
[2] 54% kill after 86 days.
[3] 56% kill after 29 days, and 21% kill after 37 days.

Table 5.—Degree of damage resulting from continuous exposure of *Attagenus piceus* larvae to treated wool, and mortality of the initial infestation of *A. piceus* larvae following continuous exposure to treated wool.

Compound	Degree of Damage[1] Age of Treatment, Days					Per Cent Kill Age of Treatment, Days				
	10	22	35	57	79	10	22	35	57	79
Mixed Alkyl and Acyl-Alkyl Phosphate Esters: $((RO)_2P(O)OR')$										
Diethyl octyl $R=C_2H_5$, $R'=C_8H_{17}$	2	2	2	2	2.7	13	33	100		
Acetyl diethyl $R=C_2H_5$, $R'=CH_3CO$	2.3	3	3	3	3	0	23	67	77	80
Dialkyl Aryl Phosphate Esters: $((RO)_2P(O)OR')$										
Diethyl phenyl $R=C_2H_5$, $R'=C_6H_5$	3	3.7	3.7	3.7		7	17	43	53	
Diethyl *o*-nitrophenyl $R=C_2H_5$, $R'=O_2NC_6H_4$	1	1.3	1.3	1.7	1.7	50	87	100		
Diethyl *p*-nitrophenyl $R=C_2H_5$, $R'=O_2NC_6H_4$	1	1	1	1	1	63	87	100		
Diethyl *p*-nitrophenyl thiono $R=C_2H_5$, $R'=O_2NC_6H_4$	1	1	1	1	1	13	93	100		
Tetraalkyl Pyrophosphate and Related Esters: $((RO)_2P(O)OP(O)(OR)_2)$										
Tetraethyl $R=C_2H_5$	1.7	2	2.7	3	3	43	90	100		
Tetraethyl monothiono $R=C_2H_5$	2	2	2	2	2	57	83	100		
Ethyl methanephosphonodiethoxyphosphine oxide, $C_2H_5O(CH_3)P(O)OP(O)(OC_2H_5)_2$	2.3	2.3	2.3	2.7	3	10	63	87	100	
Ethyl ethanephosphonodiethoxyphosphine oxide, $C_2H_5O(C_2H_5)P(O)OP(O)(OC_2H_5)_2$	2.7	3	3	3	3.3	0	7	30	50	53
Ethyl butanephosphonodiethoxyphosphine oxide, $C_2H_5O(C_4H_9)P(O)OP(O)(OC_2H_5)_2$	4	4	4			0	0	0		
Ethyl benzenephosphonodiethoxyphosphine oxide, $C_2H_5O(C_6H_5)P(O)OP(O)(OC_2H_5)_2$	1.7	2.3	3	3.3	3.7	40	73	77	77	90
Ethyl *p*-chlorobenzenephosphonodiethoxyphosphine oxide, $C_2H_5O(ClC_6H_4)P(O)OP(O)(OC_2H_5)_2$	1.3	1.7	2.3	3.3	3.7	13	83	100		
unsym. Dibutyl diethyl pyrophosphate, $(C_2H_5O)_2P(O)OP(O)(OC_4H_9)_2$	1.3	2	2.7	3	3.7	73	97	100		
unsym. Diethyl di-(2-ethylhexyl) pyrophosphate, $(C_2H_5O)_2P(O)OP(O)(OCH_2CH(C_2H_5)C_4H_9)_2$	2	2.7	2.7	3	3	23	27	30	63	93
unsym. Diethyl diphenyl pyrophosphate, $(C_2H_5)_2P(O)OP(O)(OC_6H_5)_2$	2	2	3	3.3	3.3	47	97	100		
Tetrapropyl $R=C_3H_7$	3	3	3	3	3.3	13	27	53	73	90
Tetraisopropyl $R=(CH_3)_2CH$	1.3	1.3	1.3	1.3	1.3	53	100			
Di-(isopropoxy)phosphino diisopropyl phosphate, $((CH_3)_2CHO)_2POP(O)(OCH(CH_3)_2)_2$	3.7	4	4			0	0	0		
Tetrabutyl $R=C_4H_9$	3.7	4	4			3	3	3		
Tributyl ethyl pyrophosphate, $C_2H_5O(C_4H_9O)P(O)(OP(O)(OC_4H_9)_2$	3.3	3.3	3.3	3.3	3.3	13	57	90	100	
Butyl butanephosphonoethoxybutoxyphosphine oxide, $C_4H_9O(C_4H_9)P(O)OP(O)(OC_2H_5)OC_4H_9$	3.7	4	4			0	7	7		
Diethoxyphosphino ethyl acid phosphate, $(C_2H_5O)_2POP(O)(OH)OC_2H_5$	4	4	4			0	0	3		
Tetraalkyl Aryl Triphosphate Ester: $((RO)_2P(O)OP(O)(OR')OP(O)(OR)_2)$										
Phenyl tetrapropyl $R=C_3H_7$, $R'=C_6H_5$	4	4	4			3	3	3		
Alkyl Metaphosphate Ester: $(ROP(O)O)$										
Ethyl $R=C_2H_5$	3	3	3	3.3	3.7	3	3	3	27	80
Ethyl Alcohol, Absolute	4	4	4	4	4	0	0	0	3	3
Untreated Wool	4	4	4	4	4	0	0	0	0	0

[1] Degrees of damage:
1, no apparent feeding
2, nap feeding only
3, definite fiber damage
4, fibers cut so that holes made in the wool.

toxicity as the length of carbon atom chain increases, followed by a decrease in toxicity as the chain exceeds a certain length. In general the chemical activity of iso-aliphatic compounds closely parallels that of the next lower normal (straight-chain) homologue. A definite indication that insecticidal activity is similarly related to molecular structure is obtained by comparing the results obtained against *Myzus persicae* from tripropyl, tributyl, and triisobutyl phosphate. The differences in toxicity between tributyl and tripropyl, and between tributyl and triisobutyl phosphate are statistically significant, while the values obtained for tripropyl and triisobutyl phosphate are essentially equal. Kearns & Flint (1937) found the toxicity of N-substituted isopropyl and isobutyl derivatives of cyclohexylamine to be similar to that of the corresponding *N-n*-alkyl derivatives, however. In the present studies, unsaturation in an aliphatic chain had little effect on the toxicity of the molecules involved, *e.g.*, tripropyl and triallyl phosphate. Replacement of hydrogen by chlorine on the number two carbon atom of triethyl phosphate gave a significant increase in toxicity, while chlorine atoms on the two and three positions of the propyl group produced a marked but insignificant depression of toxicity. The replacement of the *para* hydrogen atom of triphenyl phosphate by a chlorine atom likewise depressed the toxicity. Alkyl groups apparently have a greater effect than aryl groups on the toxicity of the compound, since the aryl derivatives studied are relatively non toxic. The replacement of the double-bonded oxygen by sulfur has very little effect on the toxicity of triethyl phosphate.

In the light of the results discussed above, the toxicity of individual compounds in the groups mentioned must be attributed essentially to the effects of the particular substituents of the phosphate radicals and not to some inherent toxicity in the radical *per se*.

Exceedingly remarkable increases in toxicity result from the substitution of an acyl, aryl, or larger alkyl group for one of the ethyl groups of triethyl phosphate. The order of toxicity imparted by such substitution is: phenyl (aryl), less than octyl (alkyl), less than acetyl (acyl), less than nitrophenyl (substituted aryl). In general, this conclusion is in agreement with the work of Schrader (1947). Schrader proceeded further, however, in determining the effects of various phenyl substituents. He found *p*-nitrophenyl to have a greater effect on toxicity than *p*-carbethoxyphenyl which was more active than *p*-chlorophenyl. Among these three radicals, *ortho* substitution reduced the toxicity somewhat, but *m*-nitrophenyl imparted only slight toxicity to the molecule. However, in the present work diethyl *p*-nitrophenyl phosphate was found to be about six times as toxic to *Myzus porosus* as to Schrader's "aphides," while the *ortho* isomer was found to be about one-eighth as toxic as Schrader reports. Benzyl diethyl phosphate was found to be significantly less toxic than diethyl phenyl phosphate. The change in toxicity may be due to the change in molecular architecture or to a change in lipoid solubility. Increases in length of the carbon chains of the di-substituent groups also decrease the toxicity. Diaryl alkyl phosphates likewise possess only slight degrees of toxicity, though here again, the toxicity tends to increase as the normal alkyl chain is lengthened. Diaryl aralkyl phosphates were found to be insecticidally inert. The replacement of the double-bonded oxygen by sulfur definitely lowers toxicity, as shown by the results obtained with diethyl phenyl phosphate and diethyl phenyl thionophosphate, and with diethyl *p*-nitrophenyl phosphate and diethyl *p*-nitrophenyl thionophosphate.

The phosphonate esters, as a group, possess considerable toxicity to aphids but not to the house fly. Their toxicity, however, does not approach that of the substituted diethyl phosphate esters. Unfortunately, little comparison can be made between this and other groups of compounds since the derivatives studied are not parallel in structure.

The results of this investigation indicate that dialkyl phosphite and trialkyl phosphite esters are essentially non toxic to insects.

The alkyl- and arylphosphonic acids studied proved to be insecticidally inert.

The tetraalkyl pyrophosphate group exhibits high toxicity to insects. However, as the number of carbon atoms in the normal chain is increased, decreased toxicity results. As was the case with the

trialkyl phosphates, the activity of the iso-derivative studied was equal to that of the next lower homologue and was greater than its normal derivative. The phosphonophosphine oxide derivatives were less toxic than tetraethyl pyrophosphate. The replacement of one of the double-bonded oxygen atoms by sulfur in tetraethyl pyrophosphate appears to depress the toxicity of the compound somewhat.

The alkyl amidophosphates tested were found to be inactive. Schrader (1947) also found that compounds of the dialkyl N,N-dimethyl-amidophosphate type were inactive.

Phenyl tetrapropyl triphosphate was quite toxic to *Myzus porosus* but not to the house fly.

Ethyl metaphosphate showed some activity against *Myzus porosus* and the house fly.

CHEMICAL STRUCTURE AND INSECTICIDAL ACTIVITY.—Comparisons of chemical structures in relation to toxicity indicate that certain essential chemical components appear to be required to impart high toxicity in organic phosphate esters. The first of these requirements is that the phosphorus atom must be pentavalent, and that two of the valences must be linked with those of an oxygen or a sulfur atom. This is shown by comparing the results obtained from tributyl phosphate and tributyl phosphite, but is more clearly demonstrated in the case of tetraisopropyl pyrophosphate *vs.* di-(isopropoxy)-phosphino diisopropyl phosphate. A second apparent requirement is that two of the remaining valences should be occupied by OR groups. This is established by the following relationships in toxicity: tetraethyl pyrophosphate equal to tetraisopropyl pyrophosphate, both being more active than di-(isopropoxy) phosphino diisopropyl phosphate, which in turn is more active than diethoxyphosphino ethyl acid phosphate. The relationships existing between diethyl phenyl, dibutyl phenyl, butyl diphenyl, and ethyl diphenyl phosphate, and between tetraethyl, tetraisopropyl, tetrapropyl, and tetrabutyl pyrophosphate indicate that R should be either ethyl or isopropyl to yield maximum effectiveness. The third and final requirement concerns the component which must occupy the fifth phosphorus valence. The relative inactiveness of the 15 phosphonate esters tested would indicate that this valence should not be occupied by a P-R linkage. Support for this suggestion stems from a comparison of diethyl *p*-chlorobenzenephosphonate, as herein reported, with diethyl *p*-chlorophenyl phosphate, which Schrader (1947) reported as being highly active. The gross inactivity of diethyl N,N-dimethylamidophosphate should eliminate the P-NR_2 linkage. However, the high mortality of octamethyltetraamidopyrophosphate to *Myzus persicae* indicates that under certain conditions at least, trivalent nitrogen is capable of substituting for oxygen and that a P-NR_2 linkage must be given some consideration. Thus it appears that the fifth phosphorus valence should most advantageously be occupied by an -OR group, or possibly by an -NR_2 group. Consideration of this -OR group shows however, that certain restrictions must be placed upon the radical involved. Since triethyl phosphate is inactive, this radical should be designated R′. Schrader's data and the information obtained during the present investigation indicate that R′ may be a relatively large alkyl group, an acyl group, an aryl group, or an arylacyl group. Thus when R and R′ meet certain qualifications, an organic phosphate ester should apparently conform to the generalized structure $(RO)_2P(O)OR'$ in order to exhibit a high degree of insecticidal activity. These conditions account for the toxicities of all highly active compounds studied. They do not, however, account for either the toxicity of the less active ethyl metaphosphate, or the activities of diisopropyl fluorophosphonate and ethyl *p*-nitrophenyl benzenephosphonate which were not tested here. The activities reported for these last two compounds are somewhat lower than those for tetraethyl pyrophosphate, parathion, and paraoxon. Thus deviations from the suggested generalized formula may, and do, result in chemicals which exhibit insecticidal activity. Deviations from the generalized structure appear however, to produce compounds exhibiting lower orders of toxicity.

SUMMARY.—One hundred and thirty-two organic esters of phosphorus acids, namely metaphosphoric, orthophosphoric, pyrophosphoric, triphospho-

rous, and alkyl- and arylphosphoric acid, were examined for possible activity as contact insecticides against the green peach aphid, *Myzus persicae* and the house fly, *Musca domestica*. Twenty-six compounds were found to possess at least a fair degree of insecticidal activity and were tested further as contact sprays against a more resistant aphid, *Myzus porosus*, and against the house fly. Twenty-four of these compounds exhibited fair to extreme toxicity to *M. porosus*, while only 19 showed varying degrees of toxicity to the house fly. Of the 26, only three compounds proved to be active residual toxicants to the house fly. Seven compounds were shown to give good to fair protection of wool from the feeding of the larvae of the black carpet beetle, *Attagenus piceus*.

Comparisons of chemical structures in relation to toxicity indicated that certain essential chemical components were necessary to impart high toxicity in organic phosphate esters. The first requirement was that the phosphorus atom should be pentavalent, and that two of its valences should be linked with those of an oxygen or a sulfur atom. The second requirement was that two of the remaining valences should be occupied by OR groups. The limits of R were established as being ethyl or isopropyl. The third and final requirement concerned the group which must occupy the fifth valence. Evidence was presented that a P-R linkage appeared to be undesirable but that a P-NR_2 might be acceptable under certain conditions. The compounds tested however, indicated that a P-OR linkage yielded the highest toxicity. This R was shown to differ from R on valences three and four and was designated R′. R′ may apparently be a relatively large alkyl group, an acyl group, an aryl group, or an arylacyl group. The structure $(RO)_2P(O)OR'$ was therefore proposed as being necessary in order to obtain a high order of toxicity in an organic phosphate ester. All highly active compounds studied conformed to the proposed structure. The conditions imposed did not account for the activities of certain compounds showing a somewhat lower order of toxicity such as ethyl metaphosphate, diisopropyl fluorophosphonate, or ethyl *p*-nitrophenyl benzenephosphonate. Thus, even though certain deviations from the suggested generalized structure have produced insecticidally active chemicals, such deviations lower the level of toxicity. The toxicity of certain phosphoric esters was shown to increase as the length of the normal alkyl chain was increased to an optimum of about eight carbon atoms. Iso-derivatives were shown to be of the same activity as their next lower normal homologues.

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LITERATURE CITED

Anonymous (1946). Soap Blue Book. MacNair-Dorland Co., New York, N. Y.

Bruce, W. N. (1947). Aphid barrier for the laboratory. JOUR. ECON. ENT. 40: 277.

Fletcher, F. W. (1943). Testing fabric protectors. In Campbell, F. L. and F. R. Moulton, Chemical Control of Insects, Science Press Printing Company, Lancaster, Pa.

Hall, S. A. and M. Jacobson (1948). Hexaethyl tetraphosphate and tetraethyl pyrophosphate. Indust. Eng. Chem. 40: 694-99.

Hansen, J. W. (1947). Hexaethyl tetraphosphate. JOUR. ECON. ENT. 40: 600.

Kearns, C. W. and C. C. Compton (1938). The control of common red spider and thrips by the use of N,N-amyl benzyl cyclohexylamine. JOUR. ECON. ENT. 31: 625–30.

Kearns, C. W. and W. P. Flint (1937). Contact insecticidal properties of various derivatives of cyclohexylamine. JOUR. ECON. ENT. 30: 158–66.

Kearns, C. W. and R. B. March (1943). Small chamber method for testing effectiveness of insecticides against houseflies. Soap & Sanit. Chemicals 19: (2) 101–4.

Krop, S. (1948). Tetraethyl pyrophosphate (in Letters to the Editor). Chem. Eng. News 26: (15) 1108.

Lehman, A. J. (1948). The toxicology of the newer agricultural chemicals. Bul. of the Association of Food and Drug Officials 12: (3) 82–9.

Ludvik, G. F. and G. C. Decker (1947). Toxicity of certain esters of phosphorus acids to aphids. JOUR. ECON. ENT. 40: 97–100.

Roeder, K. D. (1948). The effect of anticholinesterases and related substances on nervous activity in the cockroach. Bul. Johns Hopkins Hospital **83**: (6) 587–600.
Rohwer, S. A. (1947). Warning on use of hexaethyl tetraphosphate. U.S.D.A. B.E.P.Q., April 3.
Schrader, G. (1947). The development of new insecticides. Final Report No. 714 (Revised), Item No. 8, B.I.O.S., London.

Field Experiments for Control of Oriental Fruit Moth

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The oriental fruit moth, *Grapholitha molesta* (Busck), is one of the major peach pests in Virginia, and it has caused varying amounts of injury for a number of years. Previous to 1947 this insect was held in check by the use of larval parasites chiefly *Macrocentrus ancylivorus* Roh., but with the advent of benzene hexachloride and other new organic insecticides for control of the plum curculio, the parasite population was reduced and oritenal fruit moth injury increased.

DDT was first reported to be toxic to the oriental fruit moth by Driggers (1944) and Carman & Fleschner (1944). In recent years DDT sprays have been widely used for control of the pest, but the recommendation on the number and timing of sprays varied among fruit specialists. In view of this, and the fact that an insecticide which would control both the oriental fruit moth and the plum curculio would be more desirable, experiments were started in 1949 to test some of the newer insecticides, and to determine the correct timing of the sprays under Virginia conditions. This paper gives a summary of the results for 1949 and 1950.

METHODS AND MATERIALS.—The experiments were conducted in commercial peach orchards in Albemarle County, Virginia. In 1949 the test plots were located in an orchard which had been well cared for and sprayed for oriental fruit moth control the previous year. The plots were 10 trees long and 5 trees wide. The test plots in 1950 were located in an orchard which received no sprays during the preceding year, and the plots were 10 trees long and 3 trees wide. Both orchards were planted to the Elberta variety.

The sprays were applied with a power sprayer, using a gun and about 600 pounds of pressure. Each tree received an average of approximately 5 gallons of spray at each application. Four pounds of a fine wettable sulfur were used per 100 gallons of spray at each application with all of the insecticides.

All drop fruits were picked up from under each of 10 count trees in the center of each plot during the period of first brood activity. At harvest samples of fruit from each of the 10 count trees in each plot were picked to determine injury. The drop fruits and the harvested fruits were cut to determine visible and invisible injury.

Each year the emergence and flight of the oriental fruit moth was observed by the use of bait traps suspended in the test orchard. These traps, however, were suspended in trees outside of the experimental plots. The bait mixture consisted of lignin pitch[1] and water in the ratio of 1 to 19, to which 1 cubic centimeter of terpinyl acetate per quart was added. Quart tin cans which had been painted with aluminum paint were used as traps, and these were suspended in the upper third of each of five trees.

The insecticides used in the experiments were as follows: dichloro-diphenyl trichloroethane, a 50 per cent wettable powder; parathion, a 25 per cent (1949) or a 15 per cent (1950) wettable powder; methoxychlor, a 50 per cent wettable powder; aldrin, a 45 per cent emulsifiable concentrate (1949) or a 25 per cent wettable powder (1950); dieldrin, a 25 per cent wettable powder; chlordan, a 40 per cent wettable powder; benzene hexachloride, a 10 per cent gamma isomer wettable powder; ethyl p-nitrophenyl thionobenzenephosphonate, a 25 per cent wettable powder; and acid lead arsenate.

FIELD EXPERIMENTS.—In 1949 the experiments were arranged so as to show the effectiveness of sprays applied for control of the first and second broods, the second and third broods, and the first,

[1] *Glutrin.*

Table 1.—Results of experiments for control of the oriental fruit moth in 1949.

Materials and Amount per 100 Gallons (Actual)	Spray Timing (Brood)	Per Cent Wormy		Per Cent Reduction at Harvest
		Drop Fruits[1]	Harvested Fruits	
DDT 1 lb.	1st & 2nd	0.00	1.38	77.45
DDT 1 lb.	1st, 2nd & 3rd	0.00	1.31	78.59
DDT 1 lb.	2nd & 3rd	0.42	3.54	42.16
Parathion 0.25 lb.	1st, 2nd & 3rd	0.00	0.32	94.79
Methoxychlor 1 lb.	1st, 2nd & 3rd	0.12	2.35	61.60
Aldrin 0.5 lb.	1st			
DDT 1 lb.	2nd & 3rd	0.39	2.12	65.36
Check	Unsprayed	0.67	6.12	0.00

[1] First brood only.

second and third broods of the oriental fruit moth. Table 1 gives a list of the treatments and a summary of the results. The dates of application were as follows: first brood, April 25; second brood, June 8; and third brood, July 21. The orchard in which the tests were made in 1949 had a very light infestation of the oriental fruit moth and only 42 moths were captured in five bait traps from April 12 to June 25. The results indicate that DDT sprays applied for control of the first and second broods were as effective in controlling the oriental fruit moth as a spray applied at the peak of each of the first three moth flights, and were more effective than sprays applied for control of the second and third broods. In these tests parathion was superior to DDT. Methoxychlor and aldrin did not satisfactorily control the oriental fruit moth.

In 1950 the experiments were made in an orchard which had a very high population of the oriental fruit moth. Table 2 gives a list of the treatments and a summary of the results. The sprays were applied on May 5 for control of the first brood and June 13 for control of the second brood. All infested terminals were

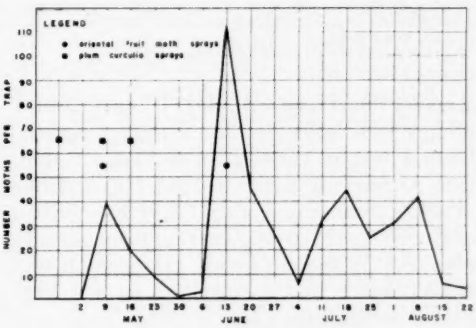

FIG. 1.—Bait trap catches of oriental fruit moths in peach trees during 1950.

collected from several trees in each plot during the first brood. On unsprayed trees the majority of the terminals and an unusually high percentage of the fruits were attacked by first brood larvae. Trees sprayed with DDT, parathion and TM-1 Ethyl p-nitrophenyl thionobenzenephosphonate had only a small number of twigs injured by the larvae. Observations indicated that the effectiveness of parathion was limited to 5 to 7 days after the application was made and fresh peach twig entries were noted before first brood

Table 2.—Results of experiments for control of the oriental fruit moth in 1950.

Materials and Amount per 100 Gallons (Actual)	Spray Timing (Brood)	Number Injured Twigs per Tree[1]	Per Cent Wormy		Per Cent Reduction at Harvest
			Drop Fruits[1]	Harvested Fruits	
DDT 1 lb.	1st & 2nd	11	6.82	17.67	82.21
DDT 1 lb.	2nd	340	73.65	83.67	15.77
Parathion .25 lb.	1st & 2nd	56[2]	17.99	16.33	83.56
Parathion .25 lb.	2nd	204	75.78	88.00	11.41
TM-1[3] .4 lb.	1st & 2nd	9	29.23	14.67	85.23
Check	Unsprayed	272	74.53	99.23	0.00

[1] First brood only.
[2] Many fresh infested twigs toward end of brood.
[3] Ethyl p-nitrophenyl thionobenzenephosphonate.

Table 3.—Control of the oriental fruit moth in plots sprayed for plum curculio control in 1950.

Materials and Amount per 100 Gallons (Actual)[1]	Per Cent Wormy		Per Cent Reduction at Harvest
	Drop Fruits[2]	Harvested Fruits	
Chlordan 1 lb.	86.75	62.86	5.71
Aldrin .5 lb.	72.42	54.55	18.18
Dieldrin .25 lb.	79.66	49.25	26.11
Benzene hexachloride .25 lb.	73.81	57.89	13.17
Benzene hexachloride .25 lb.			
Parathion .25 lb.	4.95	10.96	83.56
Parathion .25 lb.	0.53	1.00	98.50
TM-1[3] .4 lb.	3.42	0.82	98.77
Lead arsenate 2 lbs.	26.00	60.00	1.00
Check (Unsprayed)	73.93	66.67	0.00

[1] All plots received only shuck-split, shuck-fall and first cover applications. In test number 5 benzene hexachloride was applied at shuck-split and parathion was applied in the other two applications.
[2] First brood only.
[3] Ethyl p-nitrophenyl thionobenzenephosphonate.

activity had ceased. DDT and TM-1 sprays were effective for a longer period. Data given in table 2 on per cent reduction at harvest indicate that applications of DDT, parathion and TM-1 for control of the first and second broods were equally effective. A second brood application was not effective in this orchard with a high moth population since a very large percentage of the fruit was injured by the first brood. Figure 1 gives the moth catch per bait trap per week for the season. A total of 349 spring brood moths, 906 first brood moths and 945 second brood moths were captured.

Plum curculio spray plots were located in the same orchard as the oriental fruit moth experiments. Since valuable data on the control of the fruit moth were secured from these plots, the data are included. Table 3 gives a list of the treatments and data on the oriental fruit moth. The dates of the spray applications were as follows: shuck-split, April 26; shuck-fall May 5; and first cover, May 16. The plots received only three sprays, all of which were applied during the first brood period. The first (shuck-split) spray was applied about a week before the first moths emerged as can be seen in figure 1. The data secured indicate that chlordan, aldrin, dieldrin, benzene hexachloride, and lead arsenate were not effective in controlling the oriental fruit moth. Parathion and TM-1 were equally effective in controlling the first brood. When parathion sprays followed an application of benzene hexachloride the per cent wormy harvested and drop fruits showed a considerably higher percentage of oriental fruit moth injury than when parathion was used in all three sprays. No explanation is offered at this time.

Summary.—Data presented in tables 1 to 3 indicate that one spray application applied at the peak of moth flight for control of the first and second broods of the oriental fruit moth is more effective than similar sprays applied for control of the second and third broods, and equally as effective as sprays applied for control of the first, second and third broods.

In an orchard with an extremely high population of the oriental fruit moth it was necessary to apply sprays for control of the first brood in order to get satisfactory control.

DDT, TM-1 and parathion were effective in controlling the oriental fruit moth, but the last had a short residual life in comparison with the other two insecticides.

Chlordan, aldrin, dieldrin, benzene hexachloride, methoxychlor, and lead arsenate were not effective insecticides for control of the oriental fruit moth.

Literature Cited

Carman, G. E., and C. A. Fleschner. 1944. Laboratory tests on the oriental fruit moth with special reference to DDT. Jour. Econ. Ent. **37**(1): 122–3.

Driggers, Byrley F. 1944. Performance of dichlorodiphenyl trichloroethane (DDT) used against the oriental fruit moth. Jour. Econ. Ent. **37**(1): 120–1.

Attempts to Utilize Mosquito Larvae in a Bioassay[1] Method for Insecticide Residues in Animal Products

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An important step in the development of an insecticide for application to livestock is the determination of the extent to which meat and milk may be contaminated as a result of its practical use. For some of the established chlorinated hydrocarbon insecticides there have been devised sufficiently accurate methods of chemical analysis, but for others, such as chlordane and toxaphene, there is no adequately sensitive means of chemical detection. The organic chlorine method, as developed by Carter (1947), and its modifications are not sufficiently accurate to detect insecticide contamination in animal products at levels of less than 0.5 p.p.m. Current development of new insecticides for livestock ectoparasite control is hampered by the necessity of awaiting more sensitive methods to prove that their use will not seriously contaminate animal products.

All the chlorinated hydrocarbon insecticides known to be effective against livestock pests are also toxic to mosquito larvae. Deonier *et al.*[3] reported that in laboratory tests these insecticides were lethal to larvae of *Anopheles quadrimaculatus* Say at concentrations of 1 p.p.m. or less. Bushland (1947) showed that DDT was highly toxic to five species representing three genera of mosquito larvae. Deonier and co-workers (1949) found that DDT and related compounds were somewhat less toxic to *Aëdes aegypti* (L.) and *Culex quinquefasciatus* Say than to *Anopheles quadrimaculatus*, but that all three species were highly sensitive.

It is a simple matter to test insecticides in the laboratory against mosquito larvae. *Aëdes aegypti* is easily colonized, and in many areas of the South an abundance of *Culex quinquefasciatus* eggs can be readily collected from tubs of water left out of doors. Bushland & King (1943) developed a method for testing against fourth-instar larvae of *C. quinquefasciatus* and *A. aegypti*, which has been used as standard procedure at the Bureau's Orlando, Florida, laboratory and with slight modification is also employed in tests against *Anopheles quadrimaculatus*. Briefly, the method is to add the desired quantity of test material in acetone solution to 225 ml. of distilled water. Mosquito larvae tolerate up to 1 per cent of acetone in the test medium. After the solution is stirred to assure uniform distribution, counted numbers of larvae held separately in 25 ml. of distilled water are poured into the test beaker. Mortality records are taken after 24 and 48 hours.

The knowledge that DDT was lethal to mosquito larvae at great dilutions in water prompted C. C. Deonier and E. H. Peek, of the Orlando laboratory, to try the use of mosquito larvae to detect the insecticide in milk. They found (unpublished data) that DDT was rendered relatively nontoxic to mosquito larvae when as little as 10 per cent of whole milk was added to the water in which the insecticide was dispersed, and that the toxic effects of chlordane and lindane were also reduced.

This paper describes further efforts to detect insecticide contamination of milk and meat by utilization of mosquito larvae in bioassay. The insecticides tested were DDT, TDE, methoxychlor, lindane, chlordane, and toxaphene.

Tests With Emulsified Butterfat.—When chlorinated hydrocarbon insecticides contaminate milk, they are found only in the butterfat. Therefore, it was desirable to experiment with butterfat in the hope that the substance interfering with insecticidal action might be eliminated by separating butterfat from the other components of milk.

Butterfat was obtained by churning cream, melting the butter, and decanting the fat. A number of emulsifiers were tested as dispersing agents for the butterfat. It was found that butterfat could be

[1] Presented at the meeting of the Association of Economic Entomologists, Denver, Colorado, December 18–21, 1950.

[2] D. E. Hopkins reared the *Aëdes aegypti* larvae and assisted in the toxicity tests and H. V. Claborn and H. F. Beckman, all of the Kerrville, Texas, laboratory, performed the chemical treatments described herein.

[3] U. S. Bur. Ent. and Plant Quar. 1947.

emulsified by mixing 1 part of sorbitan trioleate[1] and 1 part of polyoxyethylene sorbitan trioleate[2] with 8 parts of melted butterfat. The mixture was emulsified in warm distilled water by means of a homogenizer. The emulsion had the appearance of homogenized milk.

Tests with fourth-instar *Aëdes aegypti* showed that most of the larvae could survive for 24 hours in 4-per cent butterfat emulsified as described above. Tests with such a medium were equivalent to testing whole milk containing 4 per cent of butterfat.

Butterfat samples containing 25 p.p.m. of the various insecticides were prepared by dissolving weighed amounts of the technical materials in hot butterfat. The samples were emulsified as described above and tested for toxicity to fourth-instar *Aedes aegypti*. For each test 25 larvae were immersed in 100 ml. of emulsion. The maximum concentrations tested were 4 per cent of butterfat and 1 p.p.m. of insecticide.

Samples containing DDT, TDE, methoxychlor, chlordane, toxaphene, and lindane all failed to kill the larvae.

The tests indicated that separating the butterfat from other portions of milk did not eliminate the substance interfering with toxicity. The interference was so great that insecticides could not be detected in the presence of butterfat at many times the normal lethal concentration in distilled water. This butterfat method of biological testing failed at concentrations which could be easily detected by analysis for organic chlorine.

TESTS WITH ACID-TREATED BUTTERFAT.—H. V. Claborn suggested that the acid treatment in the procedure of Schechter *et al.* (1947) for the determination of DDT might serve to separate the insecticides (except methoxychlor, which is destroyed by acid treatment) from the interfering substances in butterfat. Therefore, tests were made in which 4-gram samples of butterfat containing 25 p.p.m. of insecticide were dissolved in chloroform and treated with a sulfuric acid-fuming sulfuric acid mixture. After evaporation of the chloroform the flasks were washed with 4 ml. of acetone. Theoretically, if the insecticides were not destroyed by the extraction procedure, such washings contained 0.1 mg. of insecticide. The acetone washings were diluted 1:100 with distilled water to prepare 0.25-p.p.m. concentrations of the insecticides. The preparations were tested at that and further dilutions, with 25 larvae of *Aëdes aegypti* in 100 ml. of water at 80° F.

For comparative purposes tests were made with standard dilutions of the insecticides made by dissolving the chemicals directly in acetone and adding the solutions to distilled water according to the accepted procedure.

In tests with DDT and TDE the samples subjected to acid extraction killed no larvae at the highest concentration tested, although all the standards caused complete mortality at that and at lower concentrations.

The acid-extraction procedure is not supposed to destroy the insecticides, and chemists have reported high recoveries of DDT and TDE by the Schechter method.

Cloudy precipitates formed when the acetone washings of butterfat extracts were added to water, but adding standard acetone solutions of the insecticides produced no such cloudiness. It seems that this turbidity was caused by a substance in the butterfat which was not destroyed by acid extraction, and that this substance interfered with the toxicity of the insecticides.

The acetone washings of butterfat contaminated with 25 p.p.m. of lindane caused a similar turbidity, but the samples were toxic to *Aëdes aegypti* larvae.

Three butterfat samples containing 25 p.p.m. of lindane were extracted and the extracts tested in comparison with standard acetone solutions of the insecticide. The results were as follows:

CONCENTRATION OF LINDANE (p.p.m.)	PER CENT MORTALITY AFTER 24 HOURS	
	Acetone Standard	Butterfat Extract
0.25	100	97
0.125	69	70
0.062	10	13
Control, 1 per cent of acetone	0	—

These data indicate that lindane in butterfat was completely recovered after acid extraction. Because in each of the three tests the extracted material was as toxic as the standard solution, it appears

[1] *Span 85.*
[2] *Tween 85.*

that the insoluble substance surviving acid extraction did not interfere with the larvicidal action of lindane.

The results suggest that the biological method as followed was sufficiently sensitive to detect 0.5 p.p.m. of lindane in milk of 4-per cent butterfat content. Chemical methods are more accurate.

Similar tests were made with butterfat containing 25 p.p.m. of toxaphene and chlordane. Neither insecticide could be detected in the extract at a theoretical concentration of 0.25 p.p.m. However, the standard dilutions of these materials in acetone were also ineffective at this concentration. It was therefore concluded that toxaphene and chlordane were not sufficiently toxic to fourth-instar *aegypti* for those larvae to be used in bioassay of chlordane or toxaphene.

TESTS WITH BEEF FAT.—H. V. Claborn (unpublished report) developed a method for the separation of insecticides from beef fat. It is a modification of the method described by Schechter *et al.*, which permits the use of larger fat samples.

Chlordane was dissolved in melted beef tallow to give concentrations ranging from 1 to 8 p.p.m., and 25-gram samples were dissolved in chloroform and treated with a sulfuric acid-fuming sulfuric acid mixture. The chloroform solutions were concentrated and transferred to test tubes, and the remaining chloroform was removed by evaporation. Acetone was added in measured amounts, and the tubes were sealed and forwarded to the Orlando laboratory for testing against *Anopheles quadrimaculatus*.

The extracted samples appeared to be about as toxic as standards prepared by merely dissolving chlordane in acetone However, there was a high mortality of larvae exposed to a sample of acetone washings of a chlordane-free fat blank. Further tests must be made before anything can be concluded regarding the efficiency of this procedure.

SUMMARY.—A method of detecting insecticide contamination of milk and meat by bioassay with mosquito larvae is described. Tests were made with butterfat containing one of the chlorinated hydrocarbon insecticides—DDT, TDE, methoxychlor, lindane, chlordane, and toxaphene—against fourth-instar larvae of *Aëdes aegypti* (L.). Some constituent of emulsified butterfat rendered all these insecticides nontoxic to the larvae. Treating butterfat with sulfuric acid did not remove all the substances that interfered with the toxicity of DDT and TDE, but did eliminate the ingredient that reduced the toxicity of lindane. Toxaphene and chlordane were not sufficiently toxic to *Aëdes aegypti* larvae to be detected by the method that was effective for lindane.

In the tests with beef fat it appeared that acid treatment of larger quantities of chlordane-contaminated beef fat might be utilized in a bioassay with *Anopheles quadrimaculatus* larvae.

LITERATURE CITED

Bushland, R. C. 1947. Comparative tests with DDT and phenothiazine against two American and three New Guinea species of mosquito larvae. Mosquito News **7**: 14–7.

Bushland, R. C., and W. V. King. 1943. Laboratory tests with organic compounds as larvicides for *Culex quinquefasciatus* Say. U. S. Bur. Ent. and Plant Quar. **E-585.**

Carter, R. H. 1947. Estimation of DDT in milk by determination of organic chlorine. Indus. and Engin. Chem., Analyt. Ed. **19**: 54.

Deonier, C. C., E. S. Raun, E. H. Peek, A. N. Davis, Jr., and E. Nottingham. 1949. A comparison of DDT and other new insecticides for mosquito control. Mosquito News **9**: 150–2.

Schechter, M. S., M. A. Pogorelskin, and H. L. Haller. 1947. Colorimetric determination of DDT in milk and fatty materials. Indus. and Engin. Chem., Analyt. Ed. **19**: 51–3.

United States Bureau of Entomology and Plant Quarantine. 1947. Results of screening tests with materials evaluated as insecticides, miticides, and repellents at the Orlando, Fla., laboratory from April 1942 to April 1947. U. S. Bur. Ent. and Plant Quar. **E-733.**

SCIENTIFIC NOTES

Natural Control of the Orange Tortrix in Western Washington[1]

E. P. Breakey[2]

The orange tortrix, *Argyrotaenia citrana* (Fernald) derives its common and specific names from the fact that it has been a troublesome pest in the orange groves of California for many years. It is generally considered a subtropical species and is indigenous to the southwestern United States. More recently, however, it has become established in western Washington where it is best known as a pest of red raspberries. Breakey & Batchelor (1949a) have reported the history of this infestation. Briefly, it was a greenhouse pest for some years prior to 1933 in western Washington. By 1933, it began to appear outside in the berry fields and by 1939 it was the cause for considerable concern among the growers. By 1946, it had become a serious problem in the Puyallup Valley and the Experiment Station intensified its efforts to develop an effective control.

Observations on the natural control of the orange tortrix in western Washington have been made in connection with these studies. Inasmuch as natural control was nearly 100 per cent effective during the past season (1950) and was practically non-existent when the pest first became a problem in this area, the development of this control would seem to be worthy of record. We are apparently observing the development of natural control for a recently introduced species while no parasitic or predatory insects have been brought into the area to prey upon it.

First indication of insect parasitism was in 1947 when it was found that the larvae were being attacked by a braconid, as many as 5 per cent of the larvae collected in some fields yielding this parasite. In 1948 Johansen (1949b) found that the degree of parasitism had increased to 15 to 50 per cent by the last week in July in some fields and showed evidence of giving partial control during the picking season.

Johansen obtained a fine series of these wasps and submitted them to C. F. W. Muesebeck of the U.S. Natural Museum for identification. Muesebeck reported that it was a new species belonging to the genus *Meteorus*, near *trachynotus* Vier. In order to facilitate our studies, Johansen (*l.c.*) described it and gave it the name *argyrotaeniae* in reference to the host. Natural control of the orange tortrix has been, with few exceptions, limited to this species. The following species of parasitic hymenoptera[3] were also obtained from larvae of the orange tortrix collected in the field:

Phytodietus vulgaris Cr.
Ischnus atriceps (Cr.)
Horogenes eureka (Ashm.)
Campoletis sp.
Oncophanes atriceps (Ashm.)
Apanteles aristoteliae Vier.

Lace-wing fly larvae, lady beetle larvae and spiders also were observed feeding on orange tortrix larvae.

Eight specimens of the minute braconid, *Oncophanes atriceps* (Ashm.) all bear the same date and locality record. Since this species is gregarious in habit, the larvae feeding externally on the host caterpillar, all were probably obtained from the same tortrix larva. Three specimens of the ichneumonid, *Horogenes eureka* (Ashm.) bear the dates, May 6, July 1, and July 14—indicating more than one generation each year. Johansen states (*in litt.*) that, "All of these (according to my observations in 1948) were very unimportant as compared with *Meteorus argyrotaeniae*, and the 15 to 50 per cent natural control which I found in certain fields late that season was entirely due to this latter species."

During the summer of 1949, the degree of parasitism by *Meteorus argyrotaeniae* was so high in some berry fields that spraying for the control of the orange tortrix was unnecessary. During the summer of 1950, natural control was so effective over the entire Puyallup Valley that only a few of the growers found it advisable to spray for the control of the pest.

Johansen (*l.c.*) also obtained it from the nests of an unidentified leaf roller on plane trees in Vancouver, B. C., a locality thought to be free of the orange tortrix. What we have been witnessing, then, is the development of a high degree of natural control for an introduced pest by a native species of parasitic wasp. These observations also show that once the transition to the new host had been made, the degree of parasitism increased rapidly.

Literature Cited

Breakey, E. P. and G. S. Batchelor. 1949. The orange tortrix, a pest of raspberries in western Washington. Jour. Econ. Ent. **41**: 805–6.

Johansen, Carl. 1949. *Meteorus argyrotaeniae*, a new species of braconidae parasitic on the orange tortrix. Annals of the Ent. Soc. of America, **XLII**: 319–20.

Strawberry Leaf Roller Control in Wisconsin[1]

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The strawberry leaf roller, *Ancylis comptana fragariae* (W. & R.), is one of the most serious insect pests of strawberries in Wisconsin. During the last few years this insect has been particularly damaging in new plantings of strawberries and fields have been observed in which 50 to 75 per cent of the plants have been killed. The larvae of the leaf roller cause the damage by feeding on the leaves. At first the larvae feed on both sides of the leaves, but later they work only on the upper surface in enclosures made by folding leaflets at the midrib with silken threads (Neiswander, 1944). The leaves are skeletonized from the inside and become brown and brittle after considerable feeding has occurred.

The leaf roller has proved to be very difficult to control after the leaf is closed. Several materials have been shown to give effective control if applied before the larvae are enclosed. The infestation, however, is not usually noticed by the growers until

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[3] Determined by H. K. Townes and C. F. W. Muesebeck.
[1] Approved by Director of the Wisconsin Agricultural Experiment Station.

Table 1.—The average number of living strawberry leaf roller larvae per 50 closed leaves and per cent reduction following various insecticidal dust applications. Kenosha, Wisconsin. 1948.

Dust Treatment (35 Lbs. per Acre)	Leaf Roller Larvae per 50 Leaves			
	1-Day Counts		2-Day Counts	
	No. of Insects	Per Cent Reduction	No. of Insects	Per Cent Reduction
Parathion 2%	36	87	0	100
Toxaphene 5%	36	17	30	33
Rotenone 0.75%	30	31	35	22
DDT 5%	39	10	39	13
Chlordane 5%	40	8	42	7
Pyrethrins 0.15%	31	29	43	4
Calcium arsenate 10%	29	9	47	0
Check—no treatment	43	—	45	—

after leaf-folding has occurred, and a means of insect control at this stage would therefore be of considerable value.

In 1948 several of the newer insecticides were tested with some of the older materials. Dusts and sprays were applied to severely infested commercial plantings of strawberries which had been set out for the 1949 crop. Dust applications were made on July 15 with a power duster to plots 12 feet wide and 300 feet long. The treatments were replicated twice in randomized blocks. Sprays were applied on July 17 with a power sprayer at the rate of 100 gallons to the acre. The spray plots were 12 feet wide and 500 feet long and treatments were replicated four times.

Insect counts were taken one and two days after treatment by sampling at random 50 closed leaves in each plot and recording the number of dead and living larvae.

The insecticides used in the dust trials and insect counts following their application are summarized in table 1.

The results show that parathion was the only material of those tested which gave good control of the strawberry leaf rollers enclosed in the leaves. The other materials gave very poor control when the larvae were thus protected. The parathion took about 2 days to show its maximum effect.

This latter fact also was clearly shown in a later trial in which 8 acres of commercial strawberry plants were sprayed with parathion at the rate of 1 pound of 25 per cent wettable material to 100 gallons of spray. One day after application the control of strawberry leaf rollers was 30 per cent. Two days after treatment the control of larvae enclosed in folded leaves was 94 per cent, and 97 per cent the third day.

Table 2.—The average number of living strawberry leaf roller larvae per 50 closed leaves and per cent reduction 2 days after various spray applications. Kenosha, Wisconsin. 1949.

Spray Treatment (100 Gals. per Acre)	Leaf Roller Larvae per 50 Leaves	
	No. of Insects	Per Cent Reduction
Parathion (1 lb. 25% wettable)	6	84
Benzene hexachloride (0.5 pint 20% gamma isomer)	29	19
Tetraethyl pyrophosphate (1 pint tech.)	35	3
Check—no treatment	36	—

The results of spray tests with parathion, tetraethyl pyrophosphate and benzene hexachloride are summarized in table 2.

Of the three materials used as sprays, parathion was the only one which gave effective control of the strawberry leaf roller. The leaf roller control with parathion as shown in table 2 was poorer than that obtained in previous tests. This was probably due to less efficient coverage obtained because of a strong wind during spraying operations in the latter trial.

Literature Cited

Neiswander, R. B. 1944. Insect pests of strawberries in Ohio. Ohio Agr. Expt. Sta. Bul. 651: 3–17

Control of the Apple Leaf-Curling Midge with DDT in Codling Moth Sprays

L. R. Brown[1] and J. E. Dewey[2]

Since 1928, the apple leaf-curling midge[3] has been reported as infesting Baldwin, McIntosh and Delicious apple varieties in New England (Whitcomb 1941), and has been observed in New York in localized areas of Monroe and Wayne counties (Evans 1941). The adult insect is about 2 millimeters long, of a flesh red color, and has iridescent wings. The larvae or maggots are white, changing to orange color, and reach a maximum of 3 mm. in length (Whitcomb 1941).

The injury is apparent as an inward rolling of the edges of the apple leaves into a hard, tight roll. It is caused by the larvae of the midge feeding upon the upper surface of the leaf. As many as 55 larvae have been found in one of these rolled leaves. Injury is usually confined to the tender leaves of the current year's growth. Infested leaves often change from a normal green color to red, then brown and they may drop. Vigorous trees, with many growing tips, are more seriously infested than less vigorous trees. The extent of reduction in quantity and quality of the fruit, if any, has not been determined.

It has been reported that spraying during the growing season fails to give satisfactory control (Whitcomb 1941). This author did not state which insecticides had been used in such sprays. The most effective treatment in Massachusetts (Whitcomb 1941) has been the broadcasting of naphthalene flakes under the trees to kill the midge adults as they emerge from their pupal stage in the ground.

In 1946, two Rhode Island Greening apple orchards were found which had large infestations of the leaf-curling midge in previous years. These orchards were about 2 miles apart near Sodus, Wayne County, N. Y. Sprays of standard lead arsenate and DDT were applied to these orchards to determine if either insecticide would be effective in controlling the midge. These sprays were timed for the codling moth.

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[3] *Dasyneura mali* (Kieff.), Diptera, Cecidomyiidae.

One orchard, (A), was treated by the authors using a conventional, high pressure sprayer applying a seasonal average of 22.5 gallons per tree per application. The other orchard, (B), was treated by the grower with a sprayer[4] applying a seasonal average of 25 gallons per tree per application. The DDT-sprayed portion of each orchard received 2 pounds of 50 per cent DDT wettable powder per 100 gallons of water in the first 3 codling moth cover sprays, *i.e.*, June 26, July 9 and July 22. The other portion of each orchard received 3 pounds of standard lead arsenate plus 3 pounds of hydrated lime per 100 gallons of water in the same cover sprays and on the same dates. The lime was used as a "safener" for the lead arsenate.

On September 9, eight trees per treatment were sampled in each orchard. The sample from each tree consisted of the injured leaves on 16 terminals (twigs of the current year's growth). All samples were taken at random around the periphery of the tree at a height of about 5 feet. A leaf was counted if any amount of larval feeding injury was apparent. The data were analyzed by Student's method of t using unpaired data with equal numbers of observations. The results are presented in table 1.

Table 1.—Comparison of lead arsenate and DDT cover sprays for controlling injury of the apple leaf-curling midge.[1]

Orchard and Applicator	Insecticide	Pounds per 100 Gallons	Injured Leaves per 16 Terminals per Tree[3]	Odds
A, conventional sprayer	acid lead arsenate[2]	3	99	>99:1
	DDT, 50%WP	2	54	
B, Speed Sprayer	acid lead arsenate[2]	3	63	>99:1
	DDT, 50% WP	2	33	

[1] Sprays timed for codling moth; applied on 6/26, 7/9 & 7/22/46.
[2] Plus hydrated lime, at the rate of 3 pounds per 100 gals., as a "safener."
[3] Mean of counts from 8 trees; samples collected 9-9-46.

As indicated in table 1, there were highly significant differences, statistically, between the two insecticides in controlling midge injury in the two orchards. In the interest of practical significance, it should be noted also that, although the numbers of injured leaves were relatively high in the DDT-sprayed orchards, the extent of injury per leaf was very much less in these orchards. Under similar conditions, in the application of codling moth cover sprays, it is possible to conclude that good control of the apple leaf-curling midge will be obtained, incidentally, by the use of 2 pounds of 50 per cent DDT wettable powder per 100 gallons of water.

Subsequent observations indicate the special use of DDT in the petal fall or curculio sprays in severe midge infestations will provide better control than can be obtained by the incidental use of DDT in the first three codling moth sprays.

[4] *Speed Sprayer.*

Literature Cited

Evans, J. A. 1941. Fruit insect problems in 1939. New York State Hort. Soc. Proceedings. **86:** 20–29.

Whitcomb, W. D. 1941. The apple leaf-curling midge. Leaflet. p. 385 Massachusetts State College.

Effect of Benzene Hexachloride and Chlordane on Certain Soil Organisms[1]

H. G. Simkover and R. D. Shenefelt[2]

Since benzene hexachloride and chlordane were shown to be effective for white grub control in forest tree nurseries (Shenefelt & Simkover 1950) it was considered advisable to investigate the effects of these materials on certain soil micro-organisms.

Effect on Damping-off Fungus, *Rhizoctonia.*—Preliminary trials, employing the technique of Wilson & Choudhri (1948), revealed that when crude benzene hexachloride was sprinkled over agar slants of *Rhizoctonia*, mycelial growth was greatly inhibited. Chlordane dust failed to affect fungus growth adversely on similar cultures.

A virulent strain of *Rhizoctonia*, isolated from pine seedlings damped-off in a forest tree nursery in central Wisconsin, was inoculated into Plainfield sand treated with benzene hexachloride at one pound of the gamma isomer per acre or 10 pounds of chlordane per acre. Since Pyrax ABB was used as the insecticide diluent, it was incorporated into *Rhizoctonia* controls. The percentages of damped-off Norway pine seedlings when grown in each treatment are given in table 1. These data show that

Table 1.—Effect of chlordane and benzene hexachloride on damping-off of Norway pine seedlings grown in Plainfield sand inoculated with *Rhizoctonia*.

Insecticide (Pounds per Acre)	Rep.	Per Cent Plants Damped-off 4 Weeks After Seeding	Per Cent Plants Damped-off 5 Weeks After Seeding[1]	Per Cent Plants Failed to Emerge 5 Weeks After Seeding[2]
Chlordane 10 lbs.	1	12.5	64.0	28.5
	2	3.7	71.4	20.0
	3	11.5	61.5	25.7
	Mean	9.23	65.63	24.73
Benzene hexachloride 1 lb. gamma	1	0	20.5	2.8
	2	5.0	13.7	17.1
	3	0	21.8	8.5
	Mean	1.67	18.67	9.47
Control	1	17.8	64.2	20.0
	2	26.9	77.7	22.8
	3	18.5	65.2	34.2
	Mean	21.07	69.03	25.67

[1] Dead or showed typical *Rhizoctonia* lesions.
[2] Normal germination of seeds from this same lot ranged from 90–100% The differences may be attributed to pre-emergence damping-off.

crude benzene hexachloride inhibited damping-off, while chlordane, at the dosage employed, did not materially affect the incidence of the disease.

Effect on Mycorrhizal Fungi.[3]—One year old

[1] Results of a cooperative project between the College of Agriculture and The Wisconsin Conservation Department. Approved for publication by the Director of the Wisconsin Agricultural Experiment Station. Portion of a thesis by H. G. Simkover, submitted in partial fulfillment of requirements for the Ph.D. degree in Economic Entomology at the University of Wisconsin. Presented at the meeting of the American Association of Economic Entomologists at Denver, Colo. December 21, 1950.

[2] Research assistant and associate professor in Economic Entomology, respectively.

[3] Grateful acknowledgment is made of the assistance given by Drs. S. A. Wilde and Pietsa Mikola of the University of Wisconsin Soils Department in measurement of injury to the mycorrhizae.

white and Norway pine seedlings grown in soil treated with chlordane at 10 pounds per acre were examined for the presence of mycorrhizae. No differences could be detected in the abundance of these organisms on seedling roots grown in chlordane-treated or untreated soil. Similar examinations were made of Norway pine seedlings grown in benzene hexachloride-treated soil in the greenhouse at dosages of 5, 2.5, 1, 0.5, and 0.25 pounds of gamma per acre. Noticeable differences were evident in the numbers of mycorrhizal rootlets between the control and benzene hexachloride at one-quarter, one-half, and one pound per acre. The mycorrhizal rootlet number declined as the dosage of benzene hexachloride was increased. At the two and one-half and five pounds per acre levels, root clubbing was so severe that inspection for mycorrhizae was impossible.

EFFECT ON NITROGEN FIXING BACTERIA.—Black locust seedlings, grown for 8 weeks in Plainfield sand treated with chlordane and benzene hexachloride at 10 pounds and 1 pound of the gamma isomer per acre, respectively, showed no differences in root nodulation. The root systems of plants grown in both compared favorably with the controls in this respect.

LITERATURE CITED

Shenefelt, R. D. and H. G. Simkover. 1950. White grubs in Wisconsin forest tree nurseries. Jour. Forestry **48**: 429–34.

Wilson, J. K. and R. S. Choudhri. 1948. The effect of benzene hexachloride on soil organisms. Jour. Agr. Res. **77**: 25–32.

Determination of Grasshopper Control from Insecticide Treatments in Field-Plot Tests

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Several methods have been used in evaluating the relative effectiveness of poisoned baits and insecticides used in field-plot tests for grasshopper control. Shotwell (1942) discussed the advantages and disadvantages of four methods—pan-bait, plot-and-cage, counts per unit area, and sweeping. Although the pan-bait and the plot-and-cage methods were used almost exclusively when poisoned bait was the principal means of control, they have been practically abandoned in recent years. The counts per unit area were made of either dead or live grasshoppers and were obtained by the use of a cage. The method now generally used is sweeping with an insect net (Hinman & Cowan 1945, Weinman & Decker 1949, and others). Visual estimates are sometimes used (Brown & Putnam 1946), as well as counts of dead and affected grasshoppers (Brett & Rhoades 1946).

The experimental work on grasshopper control conducted by the Bureau of Entomology and Plant Quarantine is evaluated by the sweep-net method. However, it is known that this method gives variable results. The authors, in sampling grasshopper populations with the net at alternate hourly intervals throughout the day, found evening catches to be from 300 to 800 per cent greater than those made during the middle of the day. Counts made at the same time with a cage showed variations of only 12 to 61 per cent, an indication that this was a much more uniform and reliable method of sampling. What effect the variable results obtained with the net would have on evaluating control was somewhat questionable. As Hinman & Cowan (1945) based their use of the net method on the premise that "The ratio of the average number of grasshoppers per sweep on the treated plot to the number on the check plot would be expected to remain constant except for the effect of the treatment," it seemed that checking by both methods simultaneously would be justified. The work herein reported was carried on in alfalfa in Arizona in April 1949.

EXPERIMENTAL PROCEDURE.—Fields were selected for use after the first cutting of alfalfa had been removed and new growth was 4 to 10 inches high. Square or nearly square 1.25-acre plots, which gave areas of about 1 acre for sampling without contamination from adjoining plots, were used. One untreated plot was used in evaluating the control of two adjacent treated plots The per cent control was calculated by Abbott's formula. Samples for determining control were taken 3 days, and in some cases also 5 days, after treatment. Six baits were tested for their relative effectiveness in controlling grasshopper nymphs. As the materials and rates of application had no bearing on this study, the treatments were designated by number only. A total of 81 plots were sampled to obtain the control figures for 54 treated plots.

Sampling with the net was done by three and sometimes four men, the same group of men completing all the plots of a series at a particular sampling period. Forty-two samples were taken on each plot. A sample consisted of one, two, or three sweeps of the net, depending on the abundance of grasshoppers in the field. The number of sweeps in a particular field was set so that few, if any, blanks were recorded.

Sampling with the cage was done by the authors. The cage used was a modification of that described by Hills (1933). It was constructed entirely of galvanized metal and consisted of a band 1 inch high with an inside area of 0.5 square foot, a horizontal flange 3 inches wide extending around this band, and a cylinder 20 inches high extending up from the outside of the flange.

This height prevented nymphs from jumping out, thus eliminating the use of a top. The cage was thrust to the ground in front of the operator, and the grasshoppers on the inside were counted as they crawled about on the flange or jumped to the sides. Forty samples were taken per plot, 20 by each worker.

RESULTS.—The per cent control for the treatments and for the replicates, as determined with the cage and with the net, are shown in table 1. Treatment 3 gave the highest control and treatment 6 the lowest, with both methods of sampling. All the other treatments were variable. Analysis of variance of these data showed significant differences between treatments and between replicates. However, the important feature from the standpoint of the study was the lack of significance between results by the two sampling methods. Furthermore the low interaction between methods and treatments indicates that both methods gave similar results regardless of

[1] The authors are indebted to J. R. Parker, in charge of grasshopper research at Bozeman, Mont., for suggestions on the work and assistance in preparing the manuscript and to E. J. Hinman of the Bozeman Station, for use of data on net collections.

Table 1.—Per cent control of grasshopper nymphs as determined with a cage and an insect net on plots treated with different poison baits.

Replicate	Treatment 1		2		3		4		5		6	
	Cage	Net	Cage	Net	Cage	Net	Cage	Net	Cage	Net	Cage	Net
A	0	34	38	29	60	30	46	27	0	37	6	26
B	76	86	80	58	74	99	28	36	46	45	43	38
C	44	61	70	66	63	88	63	67	46	82	12	46
D	73	62	73	72	87	73	82	70	73	89	68	41
E	71	80	80	89	88	89	72	85	81	88	60	74
F	57	72	80	85	48	52	81	89	76	90	63	87
A′[1]	14	54	32	47	64	58	64	43	0	63	15	28
B′	92	90	85	67	88	95	55	32	75	0	35	54
C′	63	56	82	78	94	97	68	62	75	81	12	0
Mean	54.4	66.1	68.9	65.7	74.0	75.7	62.1	56.8	52.4	63.9	34.9	43.8

[1] A′, B′, and C′ are control figures for replicates, A, B, and C taken 2 days after the original sampling.

the per cent control. These two factors—nonsignificant difference between methods and low interaction between methods and treatments—indicate that the two sampling methods gave comparable results, and that either is satisfactory for determining control of grasshopper nymphs on treated plots.

CONCLUSION.—Although the sweep-net method of sampling shows great variation in the catch of grasshopper nymphs and many other insects due to time of day and meteorological conditions, thus making it of little value in population studies, its use in evaluating control on field plots seems valid if the treated and comparable untreated plots are sampled within a short period of time.

Sampling with a cage is at least as fast as with the net but is more "back breaking." It shows less variation from meteorological conditions than the insect net, and as a consequence is probably more advantageous when the weather is unfavorable for sweeping.

LITERATURE CITED

Brett, Charles H., and W. C. Rhoades. 1946. Grasshopper control in alfalfa with hexachlorocyclohexane dust. JOUR. ECON. ENT. **39**(5): 677–8.

Brown, A. W. A., and L. G. Putnam. 1946. Grasshopper control by oil solutions of DNOC sprayed from aircraft. JOUR. ECON. ENT. **39**(5): 676–7.

Hills, Orin A. 1933. A new method of collecting samples of insect populations. JOUR. ECON. ENT. **26**(4): 906–10.

Hinman, E. J., and F. T. Cowan. 1945. New insecticides in grasshopper control. U. S. Bur. Ent. and Plant Quar. **EC-1**.

Shotwell, R. L. 1942. Evaluation of baits and bait ingredients used in grasshopper control. U. S. Dept. Agr. Tech. Bul. **793**.

Weinman, Carl J., and George C. Decker. 1949. Chlorinated hydrocarbon insecticides used alone and in combinations for grasshopper control. JOUR. ECON. ENT. **42**(1): 135–42.

Mosquito Repellents Selected for Use on Man[1]

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Since 1942 several thousand chemicals have been tested in the laboratory and in the field to determine their value in repelling insects that bite man. Less than 10 per cent of these chemicals were sufficiently effective to warrant more than preliminary screening tests. The U. S. Food and Drug Administration (Draize *et al.*, 1948) considers only about 3 per cent of the promising materials safe for unrestricted use on man. This paper presents some data on the repellents that are both effective against mosquitoes and deemed safe for use on man. The effectiveness of a number of these repellents against different species of mosquitoes and other biting insects is being reported elsewhere (see Literature Cited).

These repellents have little or no odor and remain effective much longer than the essential oils, such as citronella, long used for protection against mosquitoes. However, they vary greatly in their effectiveness against different insect species and on different individuals. Tests with the repellents used by the Armed Forces during World War II have shown that mixtures of repellents are effective against a wider range of insect species and on more individuals than any one repellent used alone. Mixtures containing three repellents are effective against a wider range of insects and for longer periods than mixtures containing only two repellents.

Most of the effective repellents are solvents of paints, varnishes, and many of the plastics, and therefore must be used with caution around such materials. They do not damage wool or cotton fabrics. All of them cause some smarting when applied to mucous membranes, and some people are allergic to certain of the materials. They usually feel warm on the skin for a short period, especially if the skin is moist.

[1] The data included in this paper were obtained in connection with investigations conducted under a transfer of funds, recommended by the Committee on Medical Research, from the Office of Scientific Research and Development and from the National Military Establishment, Department of the Army, to the Bureau of Entomology and Plant Quarantine.

[2] Now with Cornell University.

Table 1.—Effectiveness of selected repellents and mixtures of repellents against several species of mosquitoes.

REPELLENT	*Aëdes aegypti*		ALASKAN *Aëdes* Spp.[1]	*Aëdes taeniorhynchus*		*Anopheles quadrimaculatus*	
	Tests	Average Repellent Time	Average Repellent Time	Tests	Average Repellent Time	Tests	Average Repellent Time
	Number	*Minutes*	*Minutes*	*Number*	*Minutes*	*Number*	*Minutes*
			Individual Repellents				
Acetoacetic acid, cyclohexyl ester	43	109	21	4	102	39	57
Bicyclo(2.2.1)-5-heptene-2,3-dicarboxylic acid, dimethyl ester, *cis*-(dimethyl carbate)	121	229	85	23	208	101	48
Cinnamic acid, propyl ester	43	173		38	237	43	74
1,2-Cyclohexanedicarboxylic acid, diethyl ester	55	176		10	96	53	57
Ethanol, 2-phenoxy-, acetate	62	166	46	8	100	58	53
Ethanol, 2,2'-thiodi-, diacetate	67	237	20	8	57	41	47
1,3-Hexanediol, 2-ethyl-(*Repellent 6-12*)	241	331	21	156	283	154	53
Hydracrylic acid, beta-phenyl-, ethyl ester	40	262	6	11	83	36	42
Phthalic acid, dimethyl ester (dimethyl phthalate)	3406	247	19	238	155	3512	108
Phthalimide, *N-sec*-butyl-	44	201	11	10	77	40	55
Propionic acid, diester with 1,5-pentanediol	33	160	10	8	95	33	93
1,2,*H*-Pyran-6-carboxylic acid, 3,4-dihydro-2,2-dimethyl-4-oxo-, butyl ester (*Indalone*)	123	1.1	9	401	168	76	41
Succinamic acid, *N,N*-dipropyl-, ethyl ester (propyl *N,N*-diethylsuccinamate)	45	322	101	10	182	47	61
Tartaric acid, diisopropyl ester	25	255	3	12	74	25	40
			Mixtures[2]				
Acetoacetic acid, cyclohexyl ester	4	232	61				
Bicyclo(2.2.1)-5-heptene-2,3-dicarboxylic acid, dimethyl ester, *cis*-(dimethyl carbate)	2	305	95			10	39
Cinnamic acid, propyl ester	4	263	32				
1,2-Cyclohexanedicarboxylic acid, diethyl ester	4	344					
Ethanol, 2-phenoxy-, acetate	3	261	49				
Ethanol, 2,2'-thiodi-, diacetate	3	244	29				
1,3-Hexanediol, 2-ethyl-(*Repellent 6-12*)	525	271	57	88	243	179	147
Hydracrylic acid, beta-phenyl-, ethyl ester	2	169	15				
Phthalimide, *N-sec*-butyl-	4	274	62				
Propionic acid, diester with 1,5-pentanediol	3	203	43				
Succinamic acid, *N,N*-dipropyl-, ethyl ester (propyl *N,N*-diethylsuccinamate)	2	203	68				
Tartaric acid, diisopropyl ester	2	290	18				

[1] 12 tests with each material, diluted with 75 per cent of alcohol.
[2] 6 parts dimethyl phthalate, 2 parts *Indalone*, and 2 parts of the material indicated.

Table 1 lists 14 mosquito repellents and 12 mixtures of repellents deemed safe to use on man, and gives some comparative results for each one. The evaluation of all materials was based on the time from the application to the first bite, and recorded as repellent time.

Because of the variation between species, it is difficult to select the material that is most effective when used alone. Against the various *Aëdes* species the three most promising repellents were propyl N,N-diethylsuccinamate, *Repellent 6-12* (2-ethyl-1,3-hexanediol), and dimethyl carbate. Dimethyl phthalate was the most effective against *Anopheles quadrimaculatus* Say.

Because only a few tests were made with most of the mixtures, no definite conclusions can be drawn. The mixture containing dimethyl carbate gave good protection in the two tests against *Aëdes aegypti* (L.), and also in the tests against Alaskan *Aëdes*. The mixture containing *Repellent 6-12* has been the most thoroughly tested, and results show a high degree of effectiveness against all the test species.

In addition to the mixtures listed in the table, formulations containing 1 part each of dimethyl phthalate, *Indalone* and *Repellent 6-12*, and those containing 2 parts of dimethyl phthalate and *Repellent 6-12* or dimethyl carbate are satisfactory for use as repellents (Travis *et al.* 1949).

LITERATURE CITED

Applewhite, K. H., and C. N. Smith. 1950. Field tests with mosquito and sand fly repellents in Alaska. JOUR. ECON. ENT. **43**(3): 353–7.

Draize, J. H., E. Alvarez, M. F. Whitesell, G. Woodard, E. C. Hagan, and A. A. Nelson. 1948. Toxicological investigations of compounds proposed for use as insect repellents. Jour. Phar. and Expt. Therap. **93**: 26–39.

Travis, B. V. 1951. Effectiveness of repellents against several species of *Anopheles* mosquitoes. Jour. Natl. Malaria Soc. (In press.)

Travis, B. V., and F. A. Morton. 1950. Insect repellents and nets for use against sand flies. N. J. Mosq. Extermin. Assoc. Proc. **37**: 154–6.

Travis, B. V., F. A. Morton, H. A. Jones, and J. H. Robinson. 1949. The more effective mosquito repellents tested at the Orlando, Fla., laboratory, 1942–47. JOUR. ECON. ENT. **42**(4): 686–94.

Travis, B. V., F. A. Morton, and C. N. Smith. 1949. Use of insect repellents and toxicants. U. S. Bur. Ent. and Plant Quar. **E-698** (Rev.)

Travis, B. V., and A. L. Smith. 1951. Tests with repellents against the stable fly. Amer. Vet. Med. Assoc. Jour. (In press.)

Travis, B. V., A. L. Smith, and A. H. Madden. 1951. Effectiveness of insect repellents against black flies, JOUR. ECON ENT. 44(3): (In press.)

Control of the Variegated Cutworm on Red Beets with DDT and Chlordane Sprays[1]

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A severe infestation of the variegated cutworm, *Peridroma margaritosa* (Haw.), occurred in red beet fields in southeastern Wisconsin during the summer of 1949. In a less severe outbreak in 1948 this cutworm completely stripped the leaves from plants in untreated red beet fields and then devoured parts of the marketable roots which resulted in a considerable loss to the growers.

Considerable work has been done on cutworm control, but on a number of different species which vary in susceptibility to various insecticides, or on species not named. For example, Carlson *et al.* (1948) found DDT more effective than benzene hexachloride for the control of climbing cutworms on peaches and apricots, while Lilly (1950) reported that toxaphene was far superior to DDT, chlordane and benzene hexachloride for the control of cutworms in corn. In laboratory tests chlordane and benzene hexachloride were found by Sun *et al.* (1948) to be more toxic than DDT to the southern armyworm, *Prodenia eridania* (Cram.). Kulash (1949) found the same to be true for the black cutworm, *Agrotis ypsilon* (Rott.), in soil surface treatments even when very high concentrations of DDT were used. Hofmaster & Greenwood (1949) found that chlordane was inferior to DDT, parathion, benzene hexachloride and toxaphene for the control of the fall armyworm, *Laphygma frugiperda* (A. & S.), but Brown *et al.* (1947) found DDT to be only slightly toxic to the pale western cutworm, *Agrotis orthogonia* Morr., toxaphene and chlordane moderately so and gamma benzene hexachloride highly toxic.

It would appear that control measures cannot be given for cutworms in general and that it is important to report the relative toxicity of insecticides to the particular species involved.

Since no recent work had been reported on the control of the variegated cutworm it was necessary under the outbreak conditions in 1949 to determine a specific control for this insect. Experiments were conducted on a 20-acre commercial red beet field which was heavily infested with the variegated cutworm. DDT and chlordane each were applied at the rate of one pound of actual toxicant to the acre in 75 gallons of spray with a high pressure machine. The applications were made about 25 days prior to harvest. The check consisted of 15 rows, ninety rods in length, and the remainder of the field was divided between the DDT and chlordane treatments.

Insect counts were taken by shaking the foliage and causing the feeding worms to fall to the ground. The total number of larvae were counted in areas of two square feet between the rows. Ten well distributed counts immediately prior to spraying showed that the cutworms averaged 38.4 larvae per two square feet. The results of similar counts taken in each treatment three days after application of the materials are given in table 1.

The data given in table 1 showed that the variegated cutworm was effectively controlled with either DDT or chlordane sprays when applied at the rate of one pound of actual toxicant per acre. Observations on several other commercial red beet fields sprayed with these materials further substantiated these results.

Table 1.—The total number of variegated cutworms per 20 square feet following spray applications of DDT and chlordane to red beets. Kenosha, Wisconsin, 1949.

Treatment	Cutworms	
	Number	Per Cent Reduction
DDT (1 lb. per acre)	16	97
Chlordane (1 lb. per acre)	52	89
Check—no treatment	469	—

Literature Cited

Brown, A. W. A., W. W. Hopewell, B. J. Wenner and H. McDonald. 1947. Laboratory assessment of organic insecticides for control of certain lepidopterous larvae. Can. Ent. **79**: 161–6.

Carlson, F. W., M. A. Yothers and F. P. Dean. 1948. DDT, benzene hexachloride and sabadilla to control climbing cutworms on peaches and apricots. JOUR. ECON. ENT. **41**: 655.

Hofmaster, R. N., and D. E. Greenwood. 1949. Fall armyworm control on forage and truck crops. JOUR. ECON. ENT. **42**: 502–6.

Kulash, W. M. 1949. Soil insecticides for control of cutworms. JOUR. ECON. ENT. **42**: 705–7.

Lilly, J. H. 1950. Toxaphene gets cutworms on corn. Iowa Farm Science. **4**: 133–4.

Sun, Y. P., W. A. Rawlins and L. B. Norton. 1948. Comparative toxicity of chlordane, DDT, benzene hexachloride and chlorinated camphene. JOUR. ECON. ENT. **41**: 91–7.

Lime-Free Calcium Arsenate Mixed with Organic Insecticides for Cotton Insect Control[1]

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Investigations have been conducted at this station for several years to determine the efficiency of mixtures of lime-free calcium arsenate with various organic insecticides for control of the boll weevil, *Anthonomus grandis* Boh., bollworm, *Heliothis armigera* (Hbn.), and cotton aphid, *Aphis gossypii* Glov. Tests by Roussel & Gaines (1949) demonstrated that lime-free calcium arsenate was as toxic as commercial calcium arsenate to the boll weevil and that the addition of parathion to lime-free calcium arsenate gave better aphid control than the addition of benzene hexachloride. Gaines & Dean (1949) and Dean & Gaines (1950) demonstrated that a combination of calcium arsenate with 1 per cent gamma benzene hexachloride or with 0.5 per cent parathion was as effective as 20 per cent toxaphene

[1] Approved for publication by the Director of the Wisconsin Agricultural Experiment Station.

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Table 1.—The average boll weevil infestation, bollworm injury and yields of seed cotton on experiment 1, College Station, Texas.

Treatment	Boll Weevil Infestation	Bollworm Injury	Yield		
			Per Plat	Per Acre	Gain Over Check
Check	52.9	16.7	40.0	1000	
20% Toxaphene-Sulphur	21.0	2.8	78.7	1968	968
Sp. Calcium Arsenate plus 1% G. BHC	19.4	4.3	79.0	1975	975
Sp. Calcium Arsenate plus 0.5% Parathion	21.8	4.2	79.7	1992	992
Min. diff. req. for sig.	4.6	2.8	11.2		

for control of the boll weevil. Yield records of small plat experiments reported by Hanna & Gaines (1950) showed these same calcium arsenate mixtures to be equal to 20 per cent toxaphene or 3 per cent gamma benzene hexachloride-5 per cent DDT for the control of moderate infestations of both boll weevils and bollworms. No damaging increase of aphids on the plats treated with the calcium arsenate mixtures was observed in any of these experiments. The tests made in 1950 and reported in this paper were a continuation of this work at the Texas Station.

Experiment 1, as shown in table 1, compares the effectiveness of lime-free calcium arsenate-1 per cent gamma benzene hexachloride, lime-free calcium arsenate-0.5 per cent parathion and 20 per cent toxaphene-40 per cent sulphur for control of boll weevils and bollworms. A randomized block plat arrangement was used. Each plat was 15 rows wide and of sufficient length to make one-tenth acre. Each treatment was replicated four times. Infestation records were made at 5-day intervals from June 19 to August 23. Nine applications of insecticides were made from June 22 to August 15 at an average rate of 15 pounds per acre.

The boll weevil infestation was severe throughout the season with many overwintering weevils emerging during May and June. Applications of insecticides were necessary to protect the early squares. A moderate bollworm infestation developed by the middle of July and persisted until the bolls matured. Severe aphid infestation on the surrounding cotton subjected the plats in this experiment to a constant migration of aphids so it was necessary to dust the whole experiment with one application of 3 per cent gamma benzene hexachloride to prevent damage.

The calcium arsenate-benzene hexachloride, calcium arsenate-parathion and toxaphene-sulphur

Table 2.—The average boll weevil infestation, bollworm injury and yields of seed cotton on experiment 2, College Station, Texas.

Treatment	Weevil Infestation	Bollworm Injury	Yield		
	Per Cent Punct. Sqs.	Per Cent Inj. Bolls	Per Plat	Per Acre	Gain Over Check
Check	54.6	10.3	58.6	879	
Sp. Calcium Arsenate plus .5% Parathion	21.1	9.2	101.0	1515	636
Clordane-DDT (10-5)	28.7	4.6	94.2	1413	534
20% Toxaphene-Sulphur	26.2	5.1	93.8	1407	528
Min. diff. req. for sig.	7.3	3.8	9.6		

Table 3.—The average boll weevil infestation, bollworm injury and yields of seed cotton on experiment 3, College Station, Texas.

Treatment	Boll Weevil Infestation	Bollworm Injury	Yield		
			Per Plat	Per Acre	Gain Over Check
Check	7.2	9.0	69.0	1725	
20% Toxaphene-Sulfur	3.8	4.8	94.4	2360	635
Sp. Calcium Arsenate plus 1% gamma BHC-2.5% DDT	3.5	3.1	94.2	2355	630
Sp. Calcium Arsenate plus 1% gamma BHC-5% DDT	3.6	2.0	96.1	2403	678
Sp. Calcium Arsenate plus 0.5% parathion-2.5% DDT	4.4	3.8	98.2	2455	730
Min. diff. req. for sig.		2.2	11.4		

mixtures did not differ significantly in boll weevil or bollworm control. All treated plats had fewer aphids than the check plats. The plats treated with toxaphene-sulphur had the least aphid infestation. The calcium arsenate-parathion treatments had fewer aphids than the plats treated with calcium arsenate-benzene hexachloride. Had the entire field been treated with any one of the insecticides, the aphid problem probably would not have become acute. There was no difference in yield between any of the insecticidal treatments.

Experiment 2, as shown in table 2, was a randomized block experiment designed to compare the effectiveness of lime-free calcium arsenate-0.5 per cent parathion, 10 per cent chlordane-5 per cent DDT and 20 per cent toxaphene-40 per cent sulphur for control of boll weevils and bollworms. The plats were 14 rows wide and 127 ft. long, which made them approximately one-seventh acre in size. Each treatment was replicated 4 times. Infestation records were made from July 1 to August 11 and eight applications of insecticides were made from July 3 to August 8 at an average rate of 12 pounds per acre.

Boll weevils increased steadily from a moderate infestation at the first of July to an extremely heavy infestation by the first of August. A moderate bollworm infestation continued from the middle of July until the bolls reached maturity.

Calcium arsenate-0.5 per cent parathion gave better control of the boll weevil than 10 per cent chlordane-5 per cent DDT. Twenty per cent toxaphene-40 per cent sulphur and 10 per cent chlordane-5 per cent DDT gave better bollworm control than the calcium arsenate-parathion. There was no significant difference in yield.

Experiment 3, as shown in table 3, compared the effectiveness of lime-free calcium arsenate-1 per cent gamma benzene hexachloride-2.5 per cent DDT, lime-free calcium arsenate-1 per cent gamma benzene hexachloride-5 per cent DDT, lime-free calcium arsenate-0.5 per cent parathion-2.5 per cent DDT and 20 per cent toxaphene-40 per cent sulphur for bollworm control. A randomized block plat arrangement with four replicates of each treatment was used. Each plat was 12 rows wide and of sufficient length to make one-tenth acre. Infestation records were made at 5-day intervals from July 11 to August 15. Six applications of insecticides were made from July 13 to August 12 at an average rate of 15 pounds per acre.

Boll weevil infestation was negligible throughout the season. Bollworm infestation was severe for the last half of July but was light for the remainder of

the season. There was no build up of aphids on any of the plats.

All treatments gave good bollworm control and yielded significantly more cotton than the untreated plats. Calcium arsenate-1 per cent gamma benzene hexachloride-5 per cent DDT gave significantly better control of the bollworm than 20 per cent toxaphene-40 per cent sulphur.

SUMMARY.—Previous experiments at this station have indicated that lime-free calcium arsenate mixtures containing 1 per cent gamma benzene hexachloride or 0.5 per cent parathion were at least as effective as 20 per cent toxaphene-40 per cent sulphur or 3 per cent gamma benzene hexachloride-5 per cent DDT-40 per cent sulphur for controlling the boll weevil and that 1 per cent gamma benzene hexachloride or 0.5 per cent parathion added to the calcium arsenate would prevent the build-up of aphids on the treated cotton.

Tests conducted during the 1950 season generally confirmed this previous work. One experiment demonstrated that calcium arsenate-1 per cent gamma benzene hexachloride, calcium arsenate-0.5 per cent parathion and 20 per cent toxaphene-40 per cent sulphur were equally effective in controlling a severe infestation of boll weevils and a moderate infestation of bollworms. In another experiment with a similar infestation, calcium arsenate-0.5 per cent parathion gave better control of boll weevils than 10 per cent chlordane-5 per cent DDT but both 20 per cent toxaphene-40 per cent sulphur and 10 per cent chlordane-5 per cent DDT gave better bollworm control. A third experiment where the only important infestation was of bollworms indicated that calcium arsenate-1 per cent gamma benzene hexachloride-5 per cent DDT was superior to 20 per cent toxaphene-40 per cent sulphur for controlling this pest but not significantly better than calcium arsenate-1 per cent gamma benzene hexachloride-2.5 per cent DDT or calcium arsenate-0.5 per cent parathion-2.5 per cent DDT. There were no important yield differences in any of these experiments. One experiment which had an unusually severe exposure to aphid attack required one application of an aphicide.

The results of three seasons' tests in the Brazos River bottoms near College Station, Texas, indicated: (1) that lime-free calcium arsenate plus 1 per cent gamma benzene hexachloride or 0.5 per cent parathion is at least as good as any insecticide in general use for controlling boll weevils, (2) that except in extreme cases the percentages of benzene hexachloride or parathion as mentioned above will prevent a build up of aphids on cotton treated with these mixtures, (3) that the addition of as much as 2.5 per cent DDT to these mixtures gives excellent bollworm control.

LITERATURE CITED

Dean, H. A., and J. C. Gaines. 1950. Comparison of dusts and sprays for cotton insect control. JOUR. ECON. ENT. **43**(2): 225–6.

Gaines, J. C., and H. A. Dean. 1949. Insecticide tests for boll weevil control during 1948. JOUR. ECON. ENT. **42**(5): 795–8.

Hanna, R. L., and J. C. Gaines. 1950. Test of insecticides for control of cotton insects during 1949. JOUR. ECON. ENT. **43**(3): 288–92.

Roussel, J. S., and J. C. Gaines. 1949. Comparison of calcium arsenates alone and mixed with organic insecticides for cotton insect control. JOUR. ECON. ENT. **42**(3): 551–2.

A Method for Estimating Zonal Areas of Apple Skin in Insecticide Residue Studies[1]

LELAND R. BROWN[2]

For the purpose of regulation, insecticide residues are usually expressed as parts of insecticide per million parts of fruit. However, the use of this means of expression might lead to erroneous conclusions when studying weathering of residues or toxicity of residues to certain insects. Amount of insecticide per unit area of fruit surface would seem to be a more logical means of expression when making studies of this kind. In attempting to express the amount of insecticide on a per unit area basis, the problems arise: (1) how the surface area of the apple should be determined, and (2) which part of the apple surface should be sampled.

Other workers have been concerned with the determination of apple surface areas. Carter & Newcomer (1933), in determining arsenical residues, assumed that the apple was a sphere of uniform density which allowed them to use a formula in determining the surface area of the whole fruit. Groves & Marshall (1935) mention the use, with the appropriate formula, of cork borer sampling for finding the surface area of portions of the apple skin; this formula is also based on the assumption that the apple is a sphere in the area sampled, presumably the cheek area. The assumption is made by Groves & Marshall that the whole surface area of certain apple varieties more nearly approximates the area of the surface of revolution of a cardioid about its axis; they also present a formula for use in this case.

It is usually the situation with conventional sprays that the calyx and stem areas of an apple receive more insecticidal deposit per unit area than the cheek of the fruit. According to Groves & Marshall this can amount to one-third of the total insecticide on the apple. These authors state: "If the total deposit is determined and the coverage is expressed as the average deposit per unit area, the result has little meaning." The writer noted frequently that conventionally sprayed fruits in Western New York showed codling moth larval injury in the cheek area, even in orchards where DDT had been used, and where heavy residues were apparent in the calyx and stem areas. It was noted that residues, as deposited by mist sprayers and wet dusters, were not heavier in the calyx and stem areas than in the cheek area of the fruit. Each of these observations indicated a need for a rapid method of determining the amount of insecticide per unit area of the cheek of the apple fruit, as this area appeared to be of critical importance.

The following slicing device was constructed to enable the surface area of the apple cheek to be found. Two ordinary, rigid butcher knives were fastened together at their handles with the sharpened edges facing in the same direction. Holes were drilled in the pointed ends of the blades (after withdrawing the temper of that portion of the blade with heat). A bolt was inserted in the holes, with a wooden spacer between the blades, and through two pieces of angle iron which were fastened to a wooden block. Thus, the blades being pivoted at their pointed ends, and their handle ends free to move toward the

[1] Adapted from an unpublished thesis, entitled: "Investigations with certain low and high air volume insecticide applicators by wet dusting and mist spraying of apple trees," submitted in 1949 by the author. Cornell Univ. Library, Ithaca, N. Y.

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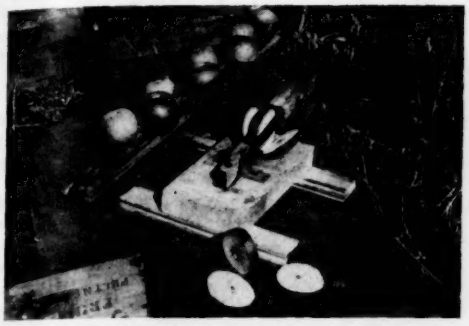

FIG. 1.—Slicing device for obtaining a disk through cheek area of apple. In foreground, note disk and calyx and stem ends. In background, note tree sampling board with nails and impaled apples.

wooden block, an apple, that was placed between the blades and block, could be sliced in 3 parts (Fig. 1). It was found necessary to have the sharpened edges of the blades converging somewhat in order to make parallel cuts through the apple. A piece of wax paper can be used between the apple and block to avoid contamination between apples.

When an apple is cut perpendicular to its axis, with such a slicing device, and the calyx and stem ends discarded, a slice or disk is obtained with the skin of the cheek area being the only portion on which the insecticide residue is found. This skin area can be determined by peeling it from the apple disk and making the necessary measurements and calculations. A more rapid method is to compute the area from a formula by assuming that this peripheral band of apple skin is a zone, or segment of a sphere. This assumption is more nearly correct if the cheek area of a symmetrical apple is used, and if the ratio of width of slice to diameter of apple is not too large.

If this assumption is made, then the area of the apple skin on the disk is calculated from the formula for area of a zone: $area = 2\pi rh$, or $area = \pi dh$, in which r = radius of the disk, d = diameter of the disk, and h = the height, or width, of the disk. It is interesting to note that the formula for area of a zone of a sphere is the same as that for the surface area of a cylinder. In all samples taken by the author, h was constant, or 1.6 centimeters (plus or minus a small fraction of a millimeter), so that the formula was simplified to: $area = 5.027d$. Thus, the area of the apple skin can become a function of the diameter of the disk.

For measuring the apple disk diameters, a piece of millimeter cross-hatched graph paper was attached to a board and covered with a piece of thin glass for the protection of the graph paper. By placing the disk over this device, the diameters could be estimated very rapidly. An average of 2 perpendicular diameters was used to reduce the error of the estimate of the area because of asymmetry in the apple. Usually 30 apple disks per sample were collected and the sum of their average diameters was used as d in the formula to obtain the total apple skin area of the sample. It was more rapid to do this, than to calculate the area of each disk and take the sum, because the total sample area was the same by either method of calculation. Disk diameters were measured after the insecticide deposit was "stripped" from the sample. After slicing, the disk can be removed by lifitinghit with an ice-pick, sticking throug the cut surface. To avoid contamination of fruit surfaces when sampling from the tree, the apples were impaled on nails driven through a board (Fig. 1).

Some advantages of using the zone method for the determination of apple skin areas are as follows: (1) For an equivalent of skin area sampled, the zone method is considerably faster than the cork borer method. Two experienced persons could determine the skin area of a sample (30 disks, each 1.6 centimeters thick, of mature Cortland variety, can have an estimated area in excess of 1000 square centimeters) in about 4 minutes. (2) The zone method can be used to determine that apple skin area which is of critical importance; the cork borer method can be used for this also.

Some disadvantages of the zone method are as follows: (1) There is a possibility of contamination of cut areas with insecticide; this is probably true with any method where the surface is cut, such as in the cork borer method. (2) Only limited skin areas are sampled which would be a disadvantage in studies of some workers. (3) The zone method, and apparently all other methods mentioned, is not well adapted to determining increase of apple skin areas due to fruit growth; this is important when it is desired to account for the "weathering" of residues as a result of fruit growth.

SUMMARY.—Reasons are given for considering the amount of insecticide per unit of cheek area of the apple as being of critical importance. A description is presented of devices and methods for estimating areas of apple skin in the cheek area. This method is based on the assumption that a disk, cut perpendicular to the axis of an apple and through the cheek area, more closely approximates a segment of a sphere, than does any other part of the apple. If this assumption is made, the skin area of the disk is computed from the formula for a zone of a sphere: $area = \pi dh$, in which d = the diameter of the disk and h = the height of the disk. When h is constant, the apple skin area becomes a function of the disk diameter. Some advantages and disadvantages of the zone method are given, relative to other methods of apple surface determination.

LITERATURE CITED

Carter, R. H., and E. J. Newcomer. 1933. Arsenical residues found on apples in the Pacific Northwest throughout a season of typical spraying with lead arsenate. JOUR. ECON. ENT. **26**(3): 572–80.

Groves, Kermit, and James Marshall. 1935. The determination of spray coverage on apples. Jour. Agr. Res. **51**(12): 1139–42.

Notes on the Life History and Habits of the Pecan Nursery Casebearer in Texas

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The pecan nursery casebearer, *Acrobasis caryivorella* Rag., is found in nearly all States where pecans are grown. Apparently it is a native American species. Phillips & Cole (1945) described the injury to nursery trees caused by this insect and commented briefly on its life history and control.

The nursery casebearer is often responsible for

[1] The writer is indebted to W. C. Pierce for assistance in rearing certain parasites and making observations on the overwintering habits of the larvae.

considerable damage to small pecan trees in nurseries and new plantings in central, southern and eastern Texas. Vigorous shoots on top-worked pecan trees may also be injured severely, but otherwise infestations do not usually develop to serious proportions on large trees. Wild walnut trees are occasionally infested by the casebearer. Hickory does not occur in the region where observations were made.

Insectary and field studies to obtain information on the life history and habits of this casebearer were started at Brownwood, Texas, in 1935, and pursued intermittently through 1945. It was found that there may be as many as four generations a year in central Texas and that its life history is somewhat similar to that of the pecan nut casebearer, *Acrobasis caryae* Grote. Detailed information concerning the various stages of the casebearer which resulted from these studies is presented in the paragraphs which follow.

EGG.—The egg is usually placed on the under or upper side of a pecan leaflet. It is not unusual to find 10 or more placed close together and sometimes there may be 70 or more. Frequently eggs are also deposited on pecan twigs, particularly near the nodes. The incubation periods of 837 eggs averaged approximately four days in August, 1935 at average temperatures of 83° F.

LARVA.—The nursery casebearer spends the winter as an immature larva in a small hibernaculum. The tough silken hibernacula vary in size, but usually they are about 1.3 mm. in length and 0.98 mm. in width. Most of the hibernacula are formed in crevices in the bark on the trunks of trees, or in old wound scars from about 1 inch below to about 1 inch above ground level. About 5 per cent of them may be situated on tree trunks from 1 inch to about 2 feet above ground level. A few are attached near buds higher up in the tree. In 1938 nearly all of several thousand reared larvae migrated down the trees on which they were placed and constructed hibernacula on the trunks near the ground.

Under field conditions the larvae form hibernacula from August to December. In the insectary 240 of 583 larvae constructed hibernacula during October, 338 during November, and 5 during the first 10 days of December. The larvae produced by the last brood of moths emerging in the fall usually overwinter in hibernacula, but larvae from earlier generations may also overwinter under certain conditions.

Overwintering larvae cut their way out of hibernacula and enter buds about the time the latter are opening. In central Texas this is usually late in March or early in April. After destroying one bud a larva may attack additional buds, or enter a leaflet petiole. Later the larvae may also enter and hollow out shoots and green twigs, or feed on the leaves. Small pecan trees in nurseries or in new plantings may be severely damaged. Vigorous trees seem to be attacked more severely than less thrifty ones.

The leaves are attacked most often by larvae of midsummer and fall generations, especially during drought periods, when tree growth and the production of suitable shoots is retarded. Larvae may skeletonize one or both sides of the individual leaflets. Large larvae may consume entire leaflets except the larger veins. Several leaflets are often tied together with silk to form a tunnel which partially protects the larva while it is feeding. The larvae rarely attack nuts under field conditions, although they will do so readily in the insectary.

Head capsule measurements of 603 hibernating larvae made during the winter of 1940–41 indicated that 11.3 per cent were in the second instar, 80.1 per cent in the third, and 8.6 per cent in the fourth.

Normally there are five larval instars. A sixth may occur when larvae are reared under unfavorable conditions. Average head-capsule measurements for larvae in the five instars were 0.20, 0.33, 0.52, 0.75, and 0.89 mm.

The average length of the larval period of 82 second-generation larvae was 19.7 days during August 1935. The minimum was 15 days and the maximum 24 days.

PUPA.—The mature larva spins a cocoon in folded leaflets that it has tied together with silken threads (Fig. 6), and pupates in this cocoon. The average length of the pupal stage of 87 second-generation pupae was 7.9 days during August 1935, the minimum 7 days and the maximum 10 days. The average length of the pupal stage of 119 third-generation pupae was 11.7 days in September, the minimum 9 days, and the maximum 15 days.

MOTH.—The overwintering generation, or spring-brood, of moths usually emerge late in April or in May, but some may emerge as late as early in June. The date the first moth emerges may vary as much as 2 or 3 weeks from year to year in central Texas.

Full grown larvae and pupae were collected at Christoval and Brownwood, Texas, in 1935 to determine the time of emergence of moths of the first, second and third generations following the spring brood. The results are tabulated below:

MOTH EMERGENCE	FIRST GENERATION	SECOND GENERATION	THIRD GENERATION
First moth	June 26	Aug. 3	Sept. 3
10 per cent	28	7	6
25 per cent	July 3	11	14
50 per cent	8	16	19
75 per cent	11	20	26
Last moth	18	29	Oct. 6

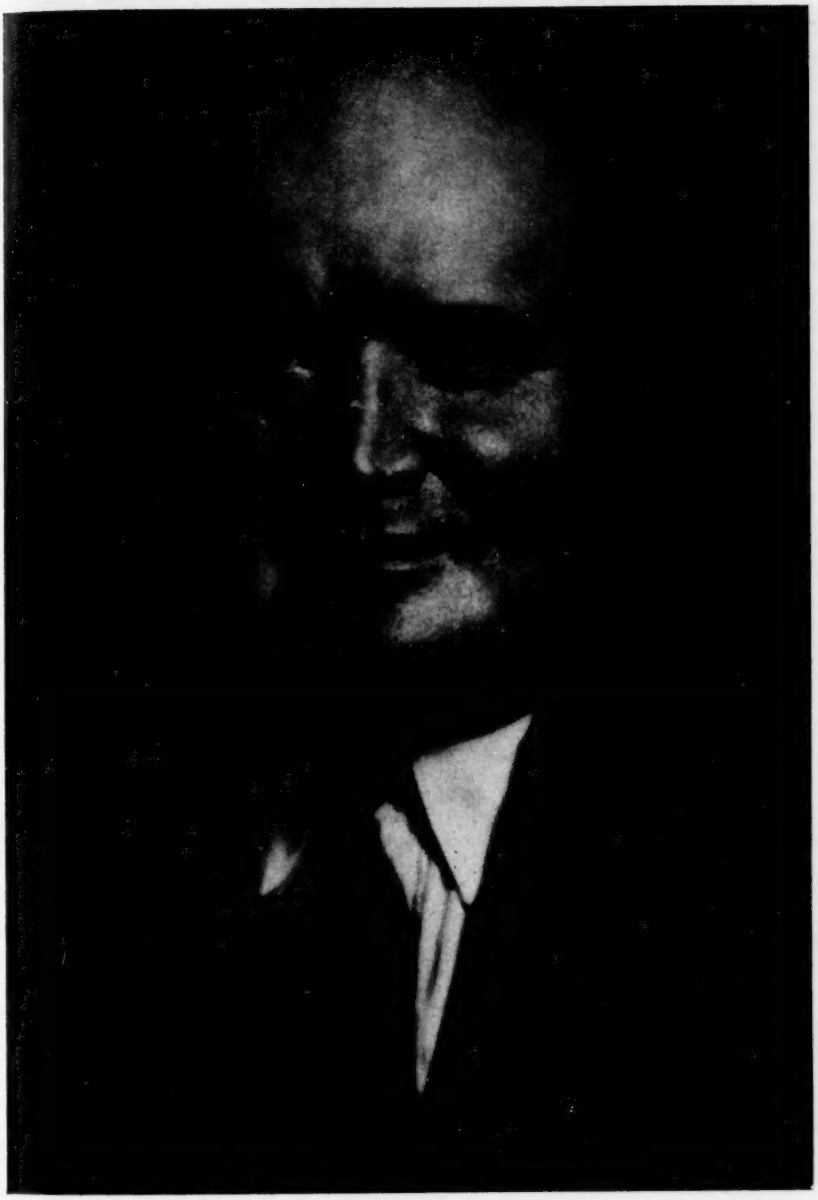
Female moths may deposit a few eggs within 24 hours after their emergence, but they are usually infertile even though the females are caged with males. Most of the eggs laid the second day after emergence are fertile and develop normally. In cage studies in August 1935, 29 second generation moths began to oviposit the second day after emergence. The oviposition periods lasted for 10 to 14 days. The average number of eggs laid by each female was 142. In one cage the average number of eggs laid by eight female moths was only 52; in another the average for nine moths was 192 eggs.

PARASITES.—The larvae are usually attacked by parasites. Adult parasites may emerge from larvae or pupae. *Nemorilla maculosa* Mg. is the most abundant parasite of the nursery casebearer in central Texas. Other primary parasites are *Apanteles carpatus* Say, *Apanteles epinotiae* Vier., *Calliephialtes grapholithae* Cress., *Gonizus hortorum* Brues, *Horismenus floridanus* Ashm., *Itoplectis conquisitor* Say, *Mesostenus thoracicus* Cress., *Neopristomerus dorsocastaneus* Vier., *Spilochalcis flavopicta* Cress., *Spilochalcis igneodis* Kirby and *Sympiesis* n. sp. The secondary parasites, *Eupelmus cyaniceps* var., *amicus* Gir., and *Phanerotoma tibialis* Hald. were reared from parasitized nursery casebearer larvae.

LITERATURE CITED

Phillips, A. M., and J. R. Cole. 1945. Insects and diseases of the pecan in Florida. Fla. Agr. Expt. Sta. Bul. 411.

OBITUARIES



William Henry White 1892-1951

William Henry White died suddenly of a heart attack while on the way to his office the morning of March 14, 1951. We should not grieve because of the loss of Bill White, but should be glad of the privilege of having known him and worked with him so long. The influence of his example on economic entomology will endure. His wise counsel, human understanding, clear thinking, and total honesty gained and kept friends for Bill and for the cause for which he worked. His friendly manner and sympathetic approach only made more striking his uncompromising attitude when it came to recommending insecticides. He will be remembered because of his insistence that no material should be used for insect control which might leave harmful residues.

The third of nine children, William H. White was born August 9, 1892, at New Town, near La Plata, Maryland. He attended public schools at College Park, Maryland, and received his degree

from the University of Maryland in 1913. He married Grace Engel, of College Park, on September 18, 1926. Mrs. White, with their two children, William E., of Hyattsville, and Herbert E., a student at the University of Maryland, survive.

Entering the then Bureau of Entomology as a scientific assistant in 1914, Mr. White was first assigned, under the leadership of the late Dr. F. C. Chittenden, to investigate insects damaging vegetables in greenhouses. His service with the Bureau was interrupted in 1918, when he enlisted in the Army. After serving in France, as a Second Lieutenant with the 32nd Machine Gun Battalion, 11th Division, he was discharged early in 1919, and immediately resumed his work with the Bureau.

Bill White was appointed leader of the Division of Truck Crop and Garden Insect Investigations in 1932. For the remainder of his life he was actively engaged in directing and conducting research on the biology, ecology, and control of a wide variety of insect and related pests attacking vegetables, sugar beets, tobacco, brambles, greenhouse, and ornamental crops and mushrooms. He organized and developed the research which resulted in perfecting methods for the control of such destructive vegetable pests as the Mexican bean beetle, melon aphid, pea weevil, pea aphid, cabbage caterpillars, wireworms, onion thrips, tomato fruitworm, mole crickets, red spider mites and garden slugs. The details are recorded in approximately 50 publications. This research included the development of many original innovations in the use of insecticide materials and equipment, and in ingenious adaptations of cultural practices, and farm sanitation for insect control. These had a profound influence on the progress of entomology and have been widely adopted in this country and abroad. Bill's interests, however, were not confined solely to that of his Division but embraced many activities of a larger scope. Among his accomplishments should be mentioned the excellent work he performed as a member of various committees dealing with the work of the Bureau, of the Department and of the scientific societies in which he held membership.

In 1932 large-scale seizures of vegetables by the health authorities, because of contamination by excessive quantities of insecticide residues, brought about a critical situation in the vegetable-producing industry. Impressed with the gravity of this development, Bill White, during the two decades following, focussed his attention on the insecticide residue problem. Much of his effort was concerned with devising methods of insect control that would avoid the hazard of poisonous or objectionable residues on vegetable products. To this end, he cooperated closely and effectively with all entomological groups, and with those agencies in the federal and State governments, who were specifically charged with the protection of the public from food poisoning. In pursuance of these activities, all programs of work on vegetable insects made provision for the testing of available insecticides to determine their possibilities as substitutes for arsenical, fluorine, and similar compounds of a highly persistent and toxic character and to research on insect control procedures that would avoid the use of insecticides. The fact that vegetable growers are currently able to place on the market large quantities of their products relatively free of poisonous insecticide residues is due, in large measure, to the information obtained in this research and distributed widely to growers of vegetables.

The outbreak of World War II found Bill alert to the needs of the military personnel and civilian populations of this country and its allies for the production of an abundant supply of vegetable food free of insect damage, insect contamination, and insecticide residues. He reorganized the work of his Division to meet the insect-control phases of the war-created emergency as it related to an increased production of vegetables commercially and in community and home gardens. He devoted special attention at this time to a widespread publicity program on the control of insects attacking vegetables.

Bill liked people, and he always enjoyed meeting and talking with them. He was well known and had many friends among the entomologists throughout the country, and also among the scientists in related fields as well as workers in the various industries having an interest in the control of vegetable and truck crop insects. His sincerity, understanding, and friendliness will long keep the memory of Bill White alive.

He was an ardent gardener and spent many happy hours growing his own vegetables. He took great pride in the crops he produced and this hobby gave him the opportunity to try out the various insect control methods and materials developed in his official capacity. He took an active part in the Victory Garden Radio Program conducted by the U. S. Department of Agriculture during World War II and offered much helpful advice to gardeners with regard to the control of insect pests.

At the time of his death, Mr. White was a member of the American Association of Economic Entomologists, the Entomological Society of Washington, the Insecticide Society of Washington, and the American Association for the Advancement of Science. In 1940 he served as Chairman of the Eastern Branch of the American Association of Economic Entomologists and for several years was the Secretary of the Biological Society of Washington.

AVERY S. HOYT
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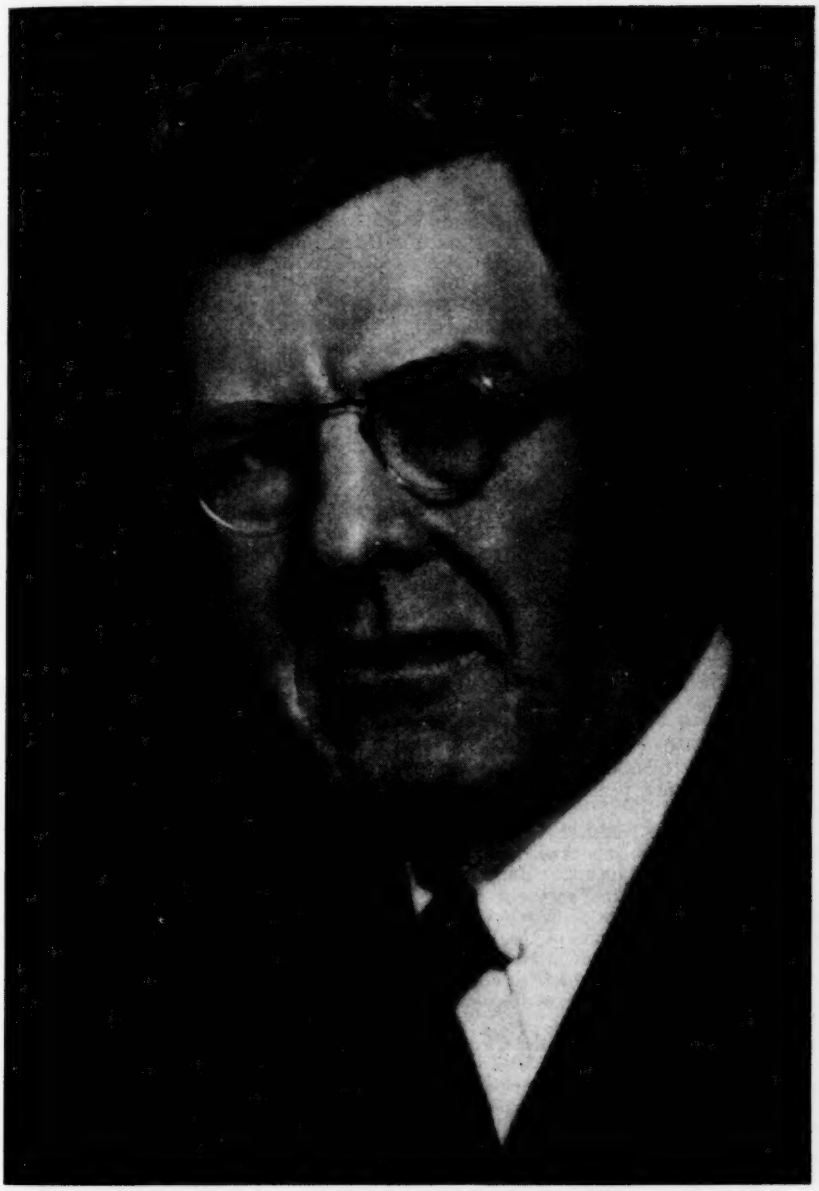


Sievert A. Rohwer, 1888–1951

Sievert A. Rohwer was stricken suddenly and died while at work on February 12, 1951. His untimely death at age 62 brought to a close a period of more than 40 years of service to the United States Department of Agriculture and to the nation.

Sievert was born at Telluride, Colorado December 22, 1888. He attended high school at Boulder. During three and one-half years in the University of Colorado, he completed all courses offered in biology, some in geology and many general courses. In 1909, he spent six months studying entomology in the museums of Paris and London. In 1923–24 he studied in the Graduate School of the Department of Agriculture, Washington, D. C.

In 1909 Mr. Rohwer was appointed by the Bureau of Entomology in the field of Forest Insect Investigations to study a destructive group of sawflies. Through his application to this project, his tremendous capacity, and his exceptional ability, he soon received recognition as an authority on the classification and identification of sawflies and other Hymenoptera. He contributed extensively to the literature in this field and his contributions have served as the basis for further work on the classification of the groups involved.

The Division of Taxonomic Investigations was

created in the Bureau in 1923 to meet the growing needs for insect identification, and Mr. Rohwer was selected to organize, develop, and direct this activity. He was called from this work in 1927 to assume the responsibilities of Business Manager of the Bureau.

The need of agriculture for greatly expanded efforts in the control of destructive insects led to a Departmental reorganization in 1928. These changes brought together in one unit all activities dealing with control and regulation of movement of plants and plant products on account of insect pests and plant diseases. The Plant Quarantine and Control Administration which was created superseded the Federal Horticultural Board and combined the former regulatory and control activities of the Board and of the Bureau of Entomology. Because of his familiarity with the various phases of the new organization, Mr. Rohwer was chosen to be Assistant Chief of the Administration, a position which he filled capably in its technical and administrative aspects from its inception in 1928 until his next assignment in 1931.

During this period the Plant Quarantine and Control Administration was confronted with serious problems on several fronts. The Mediterranean fruit fly was found in Florida. The Mexican fruit fly made its appearance in the citrus groves of South Texas. The pink bollworm of cotton had been found in the Salt River Valley of Arizona. Each of these problems called for sound, clear thinking and action on the part of the newly-organized Administration. The capacity of Assistant Chief Rohwer to analyze, organize, and execute was put to the test and he came through. What price he paid in individual effort and long hours of intense application is not disclosed by the records. His associates of that time marvelled at his endurance, persistence and determination.

In 1931 Mr. Rohwer was transferred back to the Bureau of Entomology to become Assistant Chief. He held this position until in 1934 that Bureau and the Bureau of Plant Quarantine, successor to the Plant Quarantine and Control Administration, were combined with various other units of the Department to become the present Bureau of Entomology and Plant Quarantine. Sievert Rohwer served this Bureau as Assistant Chief in charge of Regulatory Activities through December 31, 1950.

Mr. Rohwer had an important part in the work of the new Bureau. He was directly interested in the development, distribution and use of materials and equipment needed for the control of insect pests and plant diseases. This led to his active participation in administrative work associated with preparation and processing of applications for patents to protect inventions made by Bureau people; in cooperative relations with Federal land-managing agencies in problems involving control of insect pests and plant diseases; in cooperative relations with Governmental agencies responsible for regulating distribution and uses of insecticides and safeguards associated with their use; as well as in developing procedures for licensing industrial firms desiring to manufacture materials covered by Department patents, such as the aerosol bomb, and the compound containing spores of the milky white disease for use against the Japanese beetle.

During World War II, he gave a great deal of time and energy to helping farmers by planning and direction of insect surveys and interpreting the pest situation to the chemical farm equipment industries to guide them in distributing insecticides and equipment to areas where and when needed.

Despite the demands on his time and energies imposed by these many and varied activities, Mr. Rohwer had a leading part in preparing estimates of program funds and in defending them before the Bureau of the Budget and Committees in Congress. He also exercised leadership in preparing drafts of proposed legislation relating to various activities of the Bureau.

He had a high sense of the responsibilities of an assistant bureau chief. His heavy visitor list and numerous telephone calls often made him difficult to see, tending to create the impression to the uninitiated that he was somewhat aloof. Nevertheless, S. A. was always ready and seemed to derive great satisfaction in giving fatherly advice to Bureau employees confronted by a perplexing or difficult professional problem. He would draw on a seemingly inexhaustible store of background information, which he carried in his head, to provide guidance in some difficult matter. His suggestions helped many to avoid pitfalls and avert situations that would have been embarrassing. He had an unique faculty for discerning possible trends or developments and suggesting proper action to deal with events as they arose. His keen, analytical mind was quick to discern fallacies in logic, or weak points in a proposed course of action. He never hesitated to take the unpopular side of an argument if by so doing he could bring out all of the essential facts, and aid in clarifying the thinking of all concerned.

He had a wealth of contacts throughout governmental and industrial circles. Seldom did anyone of prominence in entomological or allied fields visit the Bureau headquarters in Washington without dropping in for at least a courtesy call on "Red" Rohwer. "How are you, young man?" was his customary welcome greeting to those of all ages. Responding to inquiries concerning his health he often said, jokingly, "I'm pretty good for a mean old man." He read or scanned practically all entomological and chemical literature and releases published in this country in the last decade and thus kept currently informed of developments. This fund of information enabled him to respond readily to the inquiries of official visitors.

The esteem in which Dr. Rohwer was held by the industries concerned with pesticide production and use is well summarized in the following letter from an executive of a nationally-known food packing company:

"Dr. Rohwer has been of inestimable aid to the food industry in helping us to evolve policies and committees within the American Chemical Society, the American Medical Association, the National Agricultural Chemicals Association, and elsewhere which could bring together the best brains in entomology, food industry, and the chemical industry in order to bring some rhyme and reason to the problem of chemical residues in foods.

"Dr. Rohwer has taken an active part in all of these activities and . . . he not only represented the best interests of the United States Department of Agriculture, but at the same time commanded the respect of affection of all of us in industry.

"Our Company mourns the passing of a great and courageous public servant."

Dr. Rohwer undoubtedly filled an important role as unofficial father confessor and arbiter to those in a rapidly changing and highly competitive industry. This included, in his capacity as chairman of the

Interdepartmental Committee on Pest Control, the difficult and complex task of assigning accepted and recognized common names to pesticidal chemicals.

Briefly, Sievert Rohwer might be characterized as an old-line, highly individualistic, unorthodox government official, with an intense loyalty to his convictions and an indefatigable zest for work. He had a facile use of government language. "Implementing a program," "over-all," "spell-out," and "basically," sounded quite acceptable, coming from him. He had a tendency to "cut across the board" and ignore "lines of authority." He was an ardent proponent of the term "pesticides," which he adopted to encompass all types of chemicals lethal to pests.

On January 2, 1951 Dr. Rohwer answered a call to greater responsibilities in the Agricultural Research Administration. In his new position he served as the Administrator's representative in all activities of the ARA relating to defense. He represented the Administrator in relationships required under the Defense Production Act. He served as liaison officer with all boards and agencies designated or established for defense purposes. He also assisted the Administrator in integrating program planning for research on strategic and critical agricultural materials.

Dr. Rohwer was an active member in a number of scientific societies. He was President of the Biological Society of Washington in 1925, and in 1948 served as President of the American Association of Economic Entomologists. He was corresponding secretary-treasurer of the Entomological Society of Washington from 1911 to 1934, and Society president in 1928. His keen interest in the Society and his untiring efforts in its behalf contributed in a large part to the success of this organization. From 1919 to 1924, he was a vice president of the Washington Academy of Science. He was also a member of the American Association for the Advancement of Science, Entomological Society of America, Phytopathological Society, and the Cosmos Club of Washington, and an associate member of the American Chemical Society. He was an Honorary Member of the National Pest Control Association and was often called the "godfather" of that Association.

In recognition of his significant service in food production and conservation during World War II, he was awarded the Superior Service Certificate and Medal by the United States Department of Agriculture in November 1947. In 1948 the University of Colorado conferred on him the honoray degree of Doctor of Science.

Sievert Rohwer was a prolific writer on entomological and related subjects. From 1908 to 1934, he published approximately 190 taxonomic papers. Nearly all of these dealt with sawflies, wasps, and parasitic Hymenoptera. They included descriptions of about 80 new genera and more than 1100 new species. His publications since 1934 number at least 39. Many of these discussed entomology's part in the war effort, the phenominal development of the newer insecticides and the related problems involved, and the whole field of aerosols which was of particular interest to him. He also gave many public addresses, often speaking extemporaneously and drawing upon his remarkable memory without the aid of notes.

On February 23, 1910, he married Portia Brown. He is survived by his wife, four sons, a daughter, and nine grandchildren. The surviving children are Karl S. Rohwer, Mobile Alabama; Gregor G. Rohwer, Macon, Georgia; Rolf D. Rohwer, Golden, Colorado; Donald D. Rohwer and Mrs. Portia Agadjanian, Arlington, Virginia.

Throughout his many years in the Department Dr. Rohwer served his profession well and his government beyond the call of duty. His sudden passing came as a shock to his many friends and associates throughout the country. His loss is particularly felt in the Bureau of Entomology and Plant Quarantine which he loved and served so long and well as a loyal friend and most able supporter.

F. C. BISHOPP, E. R. SASSCER,
C. F. W. MUESEBECK

PROCEEDINGS OF THE SIXTH ANNUAL MEETING

NORTH CENTRAL STATES BRANCH, AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS

Commodore Perry Hotel, Toledo, Ohio
March 21 and 22, 1951

The Sixth Annual Conference of the North Central States Branch of the American Association of Economic Entomologists was called to order by President Claud R. Neiswander. The 261 persons in attendance were extended a word of welcome by the President.

The 95 topics making up the 1951 program were divided into the following general and sectional meetings:

General Session—Systemic Insecticides and Insecticidal Residue Problems, C. R. Neiswander, *Chairman*

SECTIONS AND CHAIRMEN

Section 1—Vegetable Insects, T. C. Allen, *Chairman*
2—Stored Products and Household Insects, R. C. Smith
3—Fruit Insects, Ray Hutson
4—Extension Entomology, G. A. Lehker
5—Apiculture and Pollinating Insects, B. E. Montgomery
6—Insect Physiology and Toxicology, C. J. Weinman
7—Cereal and Forage Crop Insects, J. H. Bigger

8—Insects Affecting Man and Animals, W. N. Bruce
9—Forest and Shade Tree Insects, S. A. Graham
10—Corn Borer, T. A. Brindley
11—Insecticides and General Control Problems, R. E. Hill
12—Greenhouse Insects, L. L. English

Tours were conducted on March 21 through the facilities of the Toledo Area Sanitary District by H. A. Crandell and through the U.S.D.A. Sprayer & Duster Laboratory by Frank Irons.

First Business Session

Wednesday March 21, 1951

The following committees were appointed by President Neiswander.

Resolutions: H. M. Harris, Chairman, G. E. Marshall, and L. K. Cutkomp.

Time and Place for 1952 Meeting: C. L. Fluke, Chairman, Lee Jenkins, and S. C. Chandler.

Auditing: P. T. Ulman and J. B. Polivka.

R. T. Everly was appointed as Recorder to prepare the 1951 Proceedings.

President Neiswander called on the Secretary to present the actions taken by the Executive Committee during a meeting held on March 20.

1. The Executive Committee reviewed the plans of the Recorder for the publication of the 1951 Proceedings. The Committee recommended that the next issue be prepared with greater spacing between lines and paragraphs and that a title page be included on which could be listed the following: Branch officers, name of recorder, price and source of supply.
2. The committee recommends that the Branch pay the meeting expenses of the Recorder in addition to the annual stipend of 25 dollars.
3. Since the program of the annual meeting is becoming ever larger because of more requests for discussion topics, the Committee feels that the annual meeting should be extended into a 3-day session or that the program be limited to fewer topics and sections to permit more time for members to confer among themselves.

President Neiswander called for a vote on the extension of the annual meeting into a 3-day session.

In favor of three days—18
In favor of two days—64

President Neiswander asked for a vote on the abolition of the banquet.

In favor of abolition—66
In favor of retention—16

It was moved and seconded that the report of the Executive Committee be accepted. The motion carried unanimously.

President Neiswander called for the report of the Nominating Committee.

Roscoe Hill of Nebraska acting for Ephriam Hixson, presented the following list of candidates for officers for the succeeding year.

For *President:* T. H. Parks and R. C. Smith
For *Vice-President:* J. H. Lilly and R. T. Everly
For *Secretary-Treasurer:* A. W. Buzicky and J. W. Apple

President Neiswander asked for additional nominations from the floor.

It was moved and seconded that nominations be closed. The motion carried unanimously.

The following persons were nominated as candidates for the new Nominating Committee: G. C. Decker, Ray Hutson, R. L. Parker, Howard Deay, Oscar Hammer, and T. C. Allen.

President Neiswander introduced R. E. Campbell, President of the American Association of Economic Entomologists. Dr. Campbell expressed his gratitude for the opportunity to attend the North Central States Branch meeting. He announced the next annual meeting of the Parent Association would be held in Cincinnati from December 9 through 13, 1951. A brief review was given on the actions taken by the Executive Committee of the American Association prior to the Denver meetings. Dr. Campbell discussed the steps that have been taken on the consolidation of the two Entomological Societies.

Banquet

Wednesday, March 21, 1951

The 1951 Banquet, held in the Ballroom of the Commodore Perry Hotel, was attended by 143 persons. An enjoyable hour of organ music was provided during the dinner by the courtesy of 14 insecticide and equipment manufacturers.

C. R. Neiswander, acting as toastmaster, introduced the various members of the Program and Local Arrangements Committees and asked that the Branch members show their appreciation for the work done by a round of applause.

R. E. Campbell was presented to the group and as true Californian he eulogized the virtues of his wonderful state. His one disappointment has been the inability of his Alma Mater, the University of California, to defeat the Big Ten teams in recent Rose Bowl games.

The Banquet address was given by Dr. Louis A. Wolfanger, Professor of Land Utilization from Michigan State College. Dr. Wolfanger presented a well illustrated, highly informative talk on the World's Major Range, Forest and Farm Lands.

Final Business Session

Thursday, March 22, 1951

President Neiswander called the meeting to order.

Following a brief discussion on the desirability of having a banquet with future meetings the membership voted unanimously in favor of permitting the Local Committee to plan for a banquet if they see fit to do so. The Executive Committee was empowered to raise the registration fee to pay for meeting room expenses if the Local Committee elected to do away with the banquet.

President Neiswander called for the following reports:

Treasurer's Report

March 22, 1950 to March 20, 1951

Credits

Balance in Treasury—March 22, 1950	$ 408.47	
Sale of 420 copies of Proceedings @ $2.00 each	840.00	
Interest on bank balance	5.72	
From Am. Assoc. Econ. Entomologists for 1950 meeting expenses	125.11	
	$1,379.30	$1,379.30

Debits

Payment to—		
J. J. Kulk Co. for lapel badges	$ 20.25	
Democrat Printing Co. for 1950 programs	74.00	
Williams & Lawrence Printing Co. for 1950 menus	48.45	
Secy.-Treas. for 1950 meeting expenses	40.35	
Hotel President for rental of typewriter	4.57	
Hotel President for balance due on banquet	0.42	
The Letter Shop for mailing 1950 program	26.29	
Bell Telephone Co. for wire of sympathy to family of P. N. Annand	1.44	
The Letter Shop for mimeographing and mailing letter to membership	35.37	
Miss No-ma Itten for stenographic help	15.00	
Mrs. L. W. Everly for typing work on Proceedings	43.00	
Purdue University for envelopes	8.59	
Commercial Printing Co. Lafayette, Ind. for printing 1950 Proceedings	345.00	
R. T. Everly for postage and recorder's fee	44.60	
R. R. Express Co. for shipment of extra Proceedings from Lafayette to Madison	1.55	
Bell Telephone Co. for long distance call to Toledo, Ohio	3.56	
The Letter Shop for mimeographing and mailing letter to membership and cutting new address stencils	73.27	
C. R. Cutright for expenses incurred during meeting of Program Comm.	32.11	
R. K. Chapman for expenses incurred during meeting of Program Comm.	26.34	
The Letter Shop for mailing hotel reservation forms	30.67	
Fish & Schulkamp for Fidelity Bond on Branch Treasurer	10.00	
	$ 884.83	884.83
Balance on hand March 20, 1951	$ 494.47	

J. W. APPLE, *Sec'y Treas.*

REPORT OF AUDITING COMMITTEE

The Treasurer's books have been audited and found correct March 21, 1951.

P. T. ULMAN
J. B. POLIVKA

The Auditing Committee's report and the Treasurer's report were accepted unanimously by the membership.

REPORT OF THE RESOLUTIONS COMMITTEE

Resolution No. 1

WHEREAS, This the sixth annual meeting of the North Central States Branch of the American Association of Economic Entomologists has been a most instructive and enjoyable one, and

WHEREAS, The success of the meeting is attributable in large measure to the careful planning and diligent work of the Program Committee and the Committee on Local Arrangements, therefore

Be It Resolved, That an expression of compliment and appreciation be extended the members of these two committees, and

Be It Further Resolved, That we acknowledge our indebtedness to the invitational speakers, express our thanks to the participating agencies and compliment the Toledo Convention and Visitors Bureau, and the management of the Hotel Commodore Perry on its excellent facilities and good services.

Resolution No. 2

WHEREAS, The necessity of educating the public as to the need for and beneficial results from the use of insecticides is becoming more evident, and

WHEREAS, There is great concern over possible hazards from their general use, and

WHEREAS, The efforts of the Committee on Ec. Poisons of the Amer. Medical Assoc. are directed toward the clarification of these possible hazards, and

WHEREAS, The North Central States Branch of the A. A. E. E. recognizes the importance of the committee's efforts therefore,

Be It Resolved, That the North Central States Branch of the A.A.E.E. pledges its continued interest in and cooperation with this committee.

Resolution No. 3

WHEREAS, The failure of speakers before the sections to turn in summary papers at the time of their presentation often imposes an unnecessary amount of work on the part of the secretary and delays the appearance of the proceedings, and

WHEREAS, The accepted custom requires such a summary be submitted at the time of presentation,

Be It Resolved, That we continue to emphasize the merits for this directive and urge its absolute compliance.

Submitted by the Resolutions Committee
H. M. HARRIS, *Chairman*
G. E. MARSHALL
L. K. CUTKOMP

The report of the Resolutions Committee was accepted by a majority of the membership.

REPORT BY TIME AND PLACE COMMITTEE

The Branch had invitations from five localities which might well serve for our 1952 meeting. Two of these were from hotels and the remaining three were from entomologists in Indiana, Missouri and Minnesota. Missouri was ruled out since the 1950 meeting was held in Kansas City, Mo. The committee did not desire to make the decision between Indiana and Minnesota so President Neiswander called for a vote on the two localities.

Those favoring Lafayette, Ind.—38
Those favoring St. Paul, Minn.—43

The Committee selected the dates of March 27 and 28, 1952 for the next meeting.

C. L. FLUKE, *Chairman*
LEE JENKINS
S. C. CHANDLER

The report was accepted by the membership.

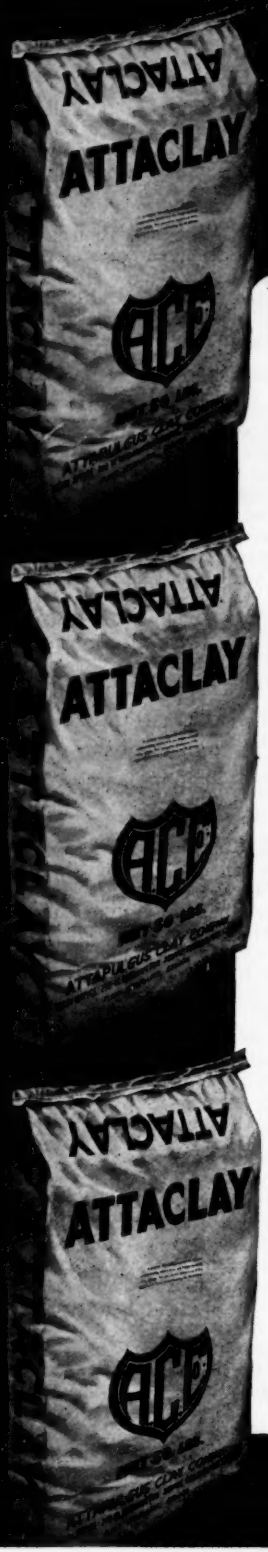
President Neiswander called on Roscoe Hill to give the results of the two elections. The new Nominating Committee will consist of T. C. Allen, Chairman, G. C. Decker, and Ray Hutson.

The following officers were elected for the ensuing year:

President—R. C. SMITH, *Manhattan, Kansas*
Vice-President—J. H. LILLY, *Ames, Iowa*
Secretary-Treasurer—J. W. APPLE, *Madison, Wisconsin*

Frank Wallace was called on to escort the new President to the rostrum. President-elect Smith expressed his appreciation for being honored with the direction of the Branch during the coming year.

Meeting adjourned by President Smith.



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